CONSULTANT REPORT

PIER
Public Interest Energy Research
CALIFORNIA ENERGY COMMISSION

Industrial/Agricultural/Water
End-Use Energy Efficiency

UV PRINTING ON PLASTICS PROJECT

Gray Davis, *Governor*

STATE OF CALIFORNIA
ENERGY COMMISSION

RESOURCES AGENCY

AUGUST 1999

CALIFORNIA ENERGY COMMISSION

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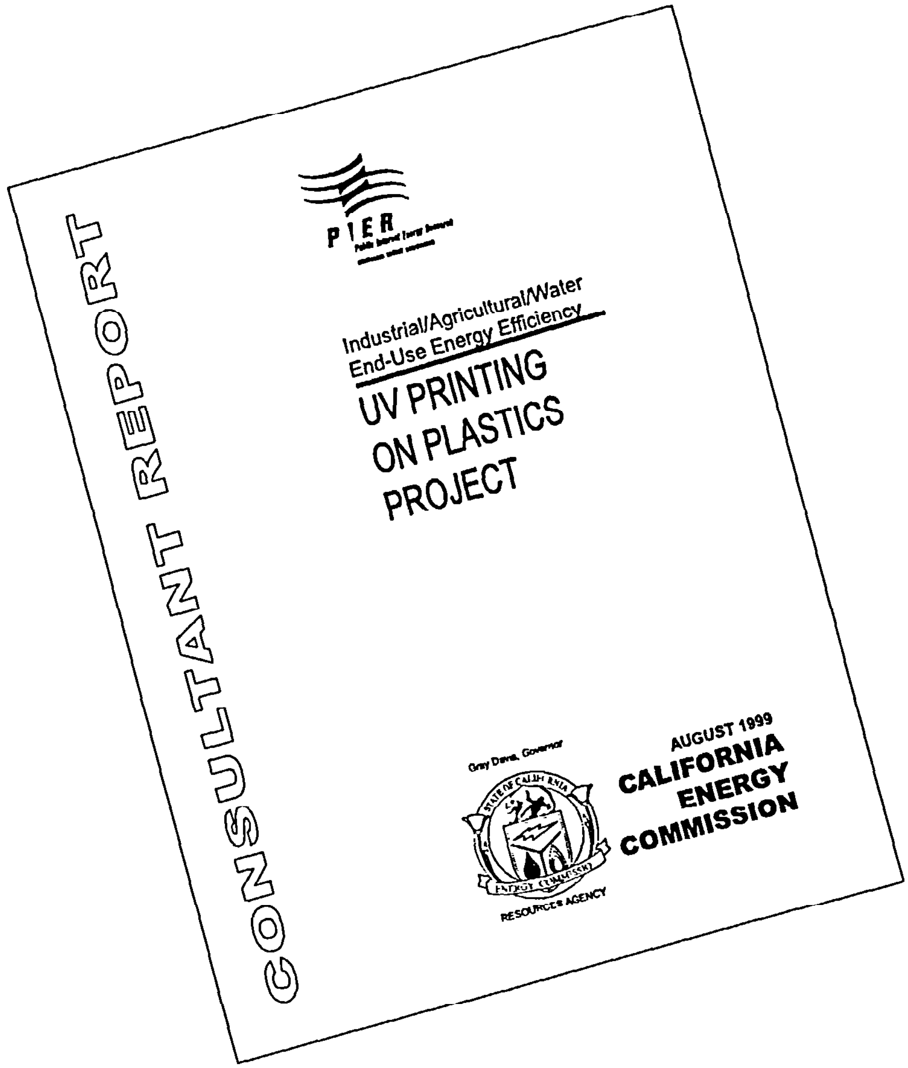

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CALIFORNIA ENERGY COMMISSION

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Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Commission), annually awards up to $62 million through the Year 2001 to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy
- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Strategic Energy Research.

In 1998, the Commission awarded approximately $17 million to 39 separate transition RD&D projects covering the five PIER subject areas. These projects were selected to preserve the benefits of the most promising ongoing public interest RD&D efforts conducted by investor-owned utilities prior to the onset of electricity restructuring.

Edison Technology Solutions (ETS) is an unregulated subsidiary of Edison International and an affiliate of Southern California Edison Company (SCE). As a result of a corporate restructuring, ETS ceased active operations on September 30, 1999. ETS' remaining rights and obligations were subsequently transferred to SCE.

What follows is the final report for the UV Printing on Plastics projects, 1 of 10 projects conducted by ETS. This project contributes to the Industrial/Agricultural/Water End-Use Energy Efficiency program.

For more information on the PIER Program, please visit the Commission's Web site at: http://www.energy.ca.gov/research/index.html or contact the Commission's Publications Unit at 916-654-5200.

Executive Summary

California's South Coast Air Basin (SCAB) encompasses a four-county area that includes Los Angeles, Orange, and portions of Riverside and San Bernardino counties. The Basin is approximately 12,000 square miles and is home to more than 14 million people. It is the second-most populous urban area in the United States and it has the Nation's dirtiest air.

The South Coast Air Quality Management District (SCAQMD) is the air pollution control agency for the SCAB. By law, the District is required to achieve and maintain healthful air quality for its residents. The Basin is out of compliance with several national and state standards for ambient air quality. One class of pollutants of grave concern to SCAQMD is referred to as volatile organic compounds (VOCs).

The SCAQMD is responsible for controlling emissions from stationary sources of air pollution. Control activities begin with the development of an Air Quality Management Plan, a blueprint for rulemaking, designed to bring the area into compliance with federal and state clean air standards. Rules are targeted to reduce emissions from specific types of equipment, industrial processes, materials, and consumer products. Many of the District's rules are industry-specific

Rule 1130 – Graphic Arts seeks to reduce VOC emissions from graphic arts operations by requiring use of emission control equipment or inks that do not contain VOCs. Emission control equipment capable of meeting the District's requirements is expensive. The substitution of solvent-borne inks with low VOC content or water-based non-VOC inks has initially imposed unsatisfactory production costs. The use of water-based inks has generated higher reject rates and a lower overall level of quality for items not rejected by quality control procedures. This is particularly true for those who print on plastic media such as grocery bags, milk cartons, bread wrappers, and other plastic packaging and wrapping products. Rule 1130 currently impacts approximately 400 flexographic printers, including approximately 20 plastic bag printers. (Appendix I, *An Initial Analysis of UV-Curable Inks for the Plastic Bag Printing Industry*.)

The use of ultraviolet (UV)-curable technology provides a viable alternative to the use of expensive emission control equipment or water-based inks. The photo-polymerization process replaces solvent-based inks with liquid monomers and oligomers together with photo-initiators that instantly harden when exposed to UV light.

UV inks act like liquid plastic. As the ink is exposed to specific wavelengths of concentrated UV radiation, a chemical reaction takes place during which the photo initiators cause the ink components to cross-link into a solid.

The use of UV-curable inks appear to offer many benefits, including the following:

- Improved Product Quality
- Improved Product Durability
- Lower Labor
- Reduced Equipment
- Improved Product
- Reduced Need for Hazardous Chemical

Edison Technology Solutions (ETS) managed the program, identified market needs, and assessed the technologies. The funding period was from January 7, 1998 to September 30, 1999.

Program Objectives

The program objectives were to:

- Demonstrate the production and economic viability of the photo-polymerization process to:
  - Provide compliance with SCAQMD Rule 1130 – Graphic Arts by reducing or eliminating the use of VOCs.
  - Match or exceed the print quality of solvent-based ink systems with emission controls, or of water-based ink systems.
  - Reduce process time requirements.
  - Reduce process energy use and energy costs.
  - Reduce maintenance costs.

Program Approach

The program consisted of three phases.

<u>Phase I -- Conduct Comparative Study of Flexographic Printing Technologies</u>

Tasks for Phase I, fully funded by SCE, of the program included:

- Preliminary technology investigation
- Preliminary assessment of target market attitudes
- Identification of equipment and supply vendors
- Preliminary cost estimates for the demonstration phase.

<u>Phase II -- Demonstrate One-Color UV Printing on Plastics</u>

Phase II was divided into four tasks designed to test and demonstrate the operational feasibility of UV-curable technology using a one-color prototypical pilot line. The California Energy Commission fully funded this phase, which began in October 1997.

The four Phase II tasks were to:

- Identify participating customer, UV ink supplier, and equipment vendor
- Engineer, design, and install pilot one-color system
- Test and simulate production of the prototypical one-color system
- Prepare pilot test results.

<u>Phase III – Pilot Test Demonstration of a Six-Color System</u>

The California Energy Commission and Associated Poly Bag Corporation were to jointly fund the Pilot Test Demonstration of a Six-Color System. But Associated Poly Bag was unable to meet cost-sharing obligations in time to meet the project's scheduling requirements.

Program Outcomes

Phase II verified the projections developed during Phase I using a customer-owned one-color press as a production test bed. The production simulation phase was an unqualified success.

- UV-curable ink systems are an economically superior choice for new flexographic printing systems and for the retrofit of solvent-borne systems.
  - Obtained full compliance with SCAQMD Rule 1130 by eliminating the use of VOC solvents.
  - Exceeded product quality (reject rates reduced to one to three percent compared to 10 to 15 percent for water-based ink systems) of water-based ink systems and matched product quality when compared to solvent-based ink systems.
  - Reduced process time to less than half the best rates achieved by water-based ink systems.
  - Reduced energy use by 75 percent and energy cost by 50 percent
  - Reduced maintenance costs because use of UV-cured ink eliminates clogging and damage to the press equipment common with other types of ink.

In addition to the above outcomes, full- production scenario analysis identified two additional benefits:

- Lower annualized costs
- Higher income potential in full-production scenarios where the printer sells additional products derived from increased press speeds.

Conclusions

UV curing technology as an alternative to installation of emission control equipment or the use of non-VOC inks is both feasible and commercially viable. It provides:

- Full compliance with SCAQMD Rule 1130.
- Higher product quality.
- Increased production rates.
- Reduced energy use by 75 percent and energy cost by 50 percent.
- Reduced maintenance costs.

Recommendations

- Establish a technology transfer program to provide information to potential new press buyers
- Research new, less expensive UV-curable ink formulations.
- Demonstrate six-color printing to foster increased commercialization of UV technology.

Abstract

Rule 1130 – Graphic Arts, issued by California's South Coast Air Quality Management District (SCAQMD), seeks to reduce emissions of volatile organic compounds (VOCs) from graphic arts operations by requiring installation of emissions control equipment or the use of inks that do not contain VOCs. As a result, local printers are forced either to use water-based ink, which can compromise product quality, or to add expensive VOC controls to their existing equipment. The goal of this project was to address these problems by developing and testing an ultraviolet (UV)-curable ink printing system that would meet Rule 1130 standards. A one-color UV-curable printing system was placed into production at the facilities of Associated Poly Bag Corporation in Anaheim, California. The data analysis demonstrated that UV-curable ink systems are technically and economically superior choices for new flexographic printing systems and for the retrofit of solvent-borne systems required to meet Rule 1130 emissions limits. Although the six-color demonstration was not done, the benefits observed in the one-color system would be realized regardless of the number of ink colors involved.

Key findings for UV systems included several benefits. These included full compliance with current Rule 1130 air quality regulations; increased production throughput and increased energy efficiency due to eliminating ink drying requirements and the emissions control equipment; better quality product with lower rejection rates than water-based ink systems; and a healthier work place environment due to the elimination of airborne vapors.

1.0 Introduction

1.1 Need for the Program

The purpose of this program was to demonstrate the feasibility of substituting UV-curable inks for the commonly used solvent-based inks in flexographic printing on plastic materials used by the product packaging industry. The program was driven by Rule 1130 – Graphic Arts of the South Coast Air Quality Management District (SCAQMD), an environmental regulation that placed stringent limitations on the emission of volatile organic compounds (VOCs) pollutants by the graphic arts industry. This regulation forced region printers to either install costly VOC emissions capture and control devices or use inks with non-VOC solvent bases.

Rule 1130 has been particularly burdensome on the flexographic segment of the graphic arts industry. This segment is responsible for a large portion of the printing that supports the product labeling and packaging industry, particularly the printing done on plastic sheet materials such as grocery bags, tortilla and bread bags, and industrial product wrapping.

1.2 Purpose and Organization of the Report

The purpose of this report is to document the development and testing of a UV-curable ink printing system and to make the results available to those undertaking similar studies. It also includes a detailed plan for commercialization. The report is organized into the following sections: Introduction; Project Description; Conclusions and Recommendations; and Appendices I through III. Appendix I contains an initial analysis of UV-curable inks for the plastic bag printing industry. Appendix II contains a cost comparison developed for bag printing operations. Appendix III contains the one-color pilot test results.

1.3 Program Objectives

The objective of this program was to collect and analyze sufficient operational and productivity data to demonstrate the feasibility of using UV-cured printing technology to print on plastic films using wide-web flexographic printing techniques. The plan was to initially demonstrate these operational and environmental benefits on a one-color system, and use lessons learned to improve and demonstrate the technology on a six-color system.

Specifically the objectives were to determine:

- Verify compliance with SCAQMD Rule 1130 – Graphic Arts by reducing the use of VOC solvents.
- Match or exceed the print quality of solvent-based ink systems with emission controls, or of water-based ink systems.
- Reduce process time requirements.
- Reduce process energy usage.
- Reduce maintenance costs.

1.4 Regulatory Environment

1.4.1 Overview

The SCAQMD is the air pollution control agency for the South Coast Air Basic (SCAB), a four-county region that includes Los Angeles and Orange counties and parts of Riverside and San Bernardino counties (Figure 1). This area of 12,000 square miles is home to more than 14 million people, about half the population of the State of California. It is the second-most populous urban area in the United States.

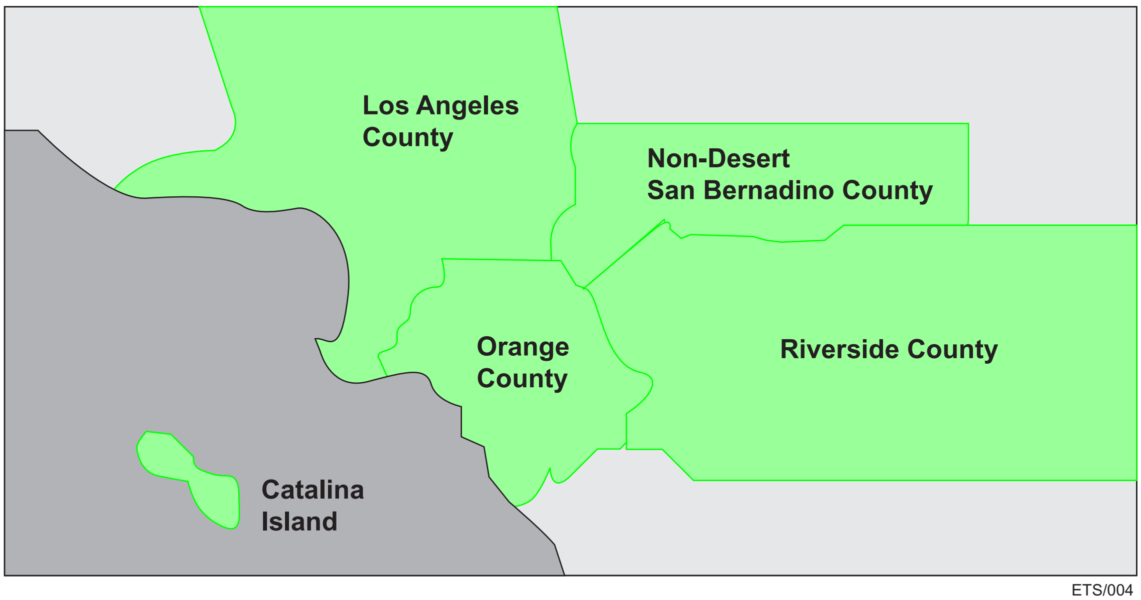

Figure 1. South Coast Air Basin

The SCAB is required by law to achieve and maintain healthful air quality for its residents. This is accomplished through a comprehensive program of planning, regulation, compliance assistance, enforcement, monitoring, technology advancement, and public education.

SCAQMD is responsible for controlling emissions from stationary sources of air pollution. These can include anything from large power plants and refineries to the corner gas station. There are about 31,000 such businesses operating under SCAQMD permits. (Reference: South Coast Air Quality Management District, *Introducing AQMD*. For more information on AQMD, see http://www.aqmd.gov/aqmd/intraqmd.html.)

SCAQMD also regulates emissions from other stationary sources including consumer products such as house paint, charcoal lighter fluid, and thousands of products containing evaporative solvents. Combined business and residential stationary sources emit about 40 percent of this area's air pollution.

The District uses a variety of strategies to reduce air pollutant emissions from stationary sources. These strategies include dissemination of public information, sponsorship of research and development (R&D) activities for promising technologies, and development of Air Quality

Management Plans that guide the District's rulemaking to bring the region into compliance with federal and state clean air standards.

The District's rules are enacted to address emissions from specific types of equipment, industrial processes, paints, solvents, and even consumer products.

1.4.2 Rule 1130

In October 1980, the SCAQMD adopted Rule 1130-Graphic Arts to regulate the emission of VOCs by the printing industry. The Rule, which has been amended several times since its adoption, establishes emission limitations for each of several printing processes. For flexographic printing processes, most commonly used to print on plastic materials, Rule 1130 limits the choice of inks, coatings, and adhesives to those having a VOC content of 300 grams per liter or less. Alternatively, printers can install emission control devices capable of providing overall VOC removal efficiencies of 67 percent.

1.4.3 The Bag Printing Industry and Rule 1130

Rule 1130 imposes a significant economic burden on an important segment of the Region's economic base. More than 400 printers in the SCAB are impacted by Rule 1130. At least 20 have announced their intention to close or move out of the Region because they cannot meet the Rule's emission limitations and remain economically competitive.

While the Rule impacts all segments of the graphic arts industry, it is particularly burdensome to flexographic process operators. These operators print on plastic and metallic materials such as grocery bags, foil labels, and corrugated paper goods. The research and commercialization efforts addressed by this report focus on plastic bag printers.

Within the SCAB, there are about 20 bag printers who print on plastic substrates including polyethylene and polypropylene. These printers produce the bags for tortillas, produce, frozen food, ice, pharmaceuticals, fertilizer, and a variety of other commercial products.

The bags are manufactured using a series of extrusion, printing, and converting operations. Raw ingredients, in the form of beads or pellets, are fed into an extruder that produces a continuous film or sheet of polyethylene or polypropylene. In some cases, when the film exits the extruder, it passes through a corona treater that adjusts the surface tension of the film to a predetermined level to prepare the film for printing. The treater also removes wax, slip agents, and plasticizers from the surface of the film to enhance ink adhesion. The extruded film is then printed with a flexographic printing press to produce designs and words on the bags. The final process, called converting, forms the printed plastic into bags. (Appendix I, *An Initial Analysis of UV-Curable Inks for the Plastic Bag Printing Industry*.)

1.5 Program Plan

The program began in July 1997 with the development of a project plan divided into three phases. Initiation of each phase depended on the success of its predecessor.

Southern California Edison (SCE) provided $26,000 to begin Phase I of this program from research funds obtained from the California Public Utilities Commission (PUC) prior to the deregulation of the State's electric utility industry under Assembly Bill 1890 (AB 1890). Phases

II and III were to be funded in part by a $250,000 Public Interest Energy Research (PIER) Transition Program grant from the California Energy Commission (Commission).

The three phases included feasibility investigation and technology demonstration activities (Figure 2 and Table 1).

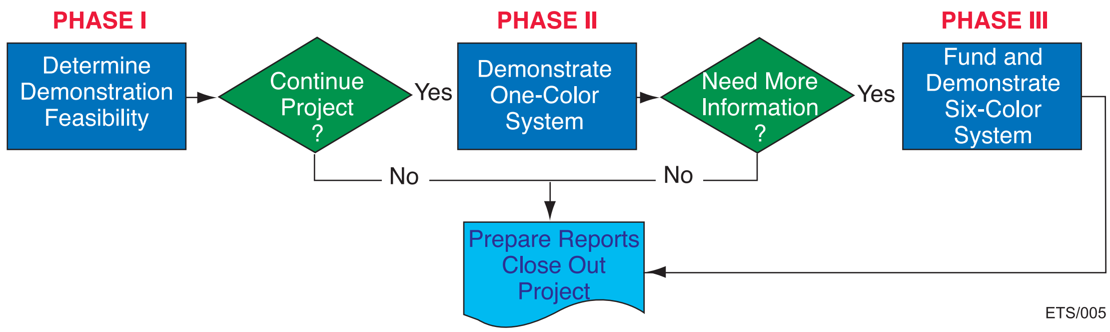

Figure 2. Program Phases

Table 1. Program Tasks

Task #	Description
Phase I	
1.0	Compare UV printing on plastic bags to alternative printing technologies.
2.0	Select pilot test demonstration site; develop project plan.
3.0	Solicit cooperative proposals from UV; system vendors and ink suppliers; develop detailed project budget and plan.
Phase II	
4.1	Consummate contracts with participating customer, UV ink supplier, and UV equipment vendor.
4.2	Design, fabricate, and install pilot one-color UV flexographic system at participating customer site.
4.3	Perform customer test of one-color system under actual production conditions.
5.0	Document one-color pilot test results.
Phase III	
6.0	Design six-color UV production system.
7.0	Procure demonstration system.
8.0	Install and test six-color UV system.
9.0	Place six-color system in production.
10.0	Define commercialization opportunities.
11.0	Conduct technology transfer activities, including conduct seminars and exhibitions.
12.0	Prepare final report.
13.0	Publish findings, present final report to California Energy Commission.

1.5.1 Schedule

Figure 3 shows the proposed schedule for this program.

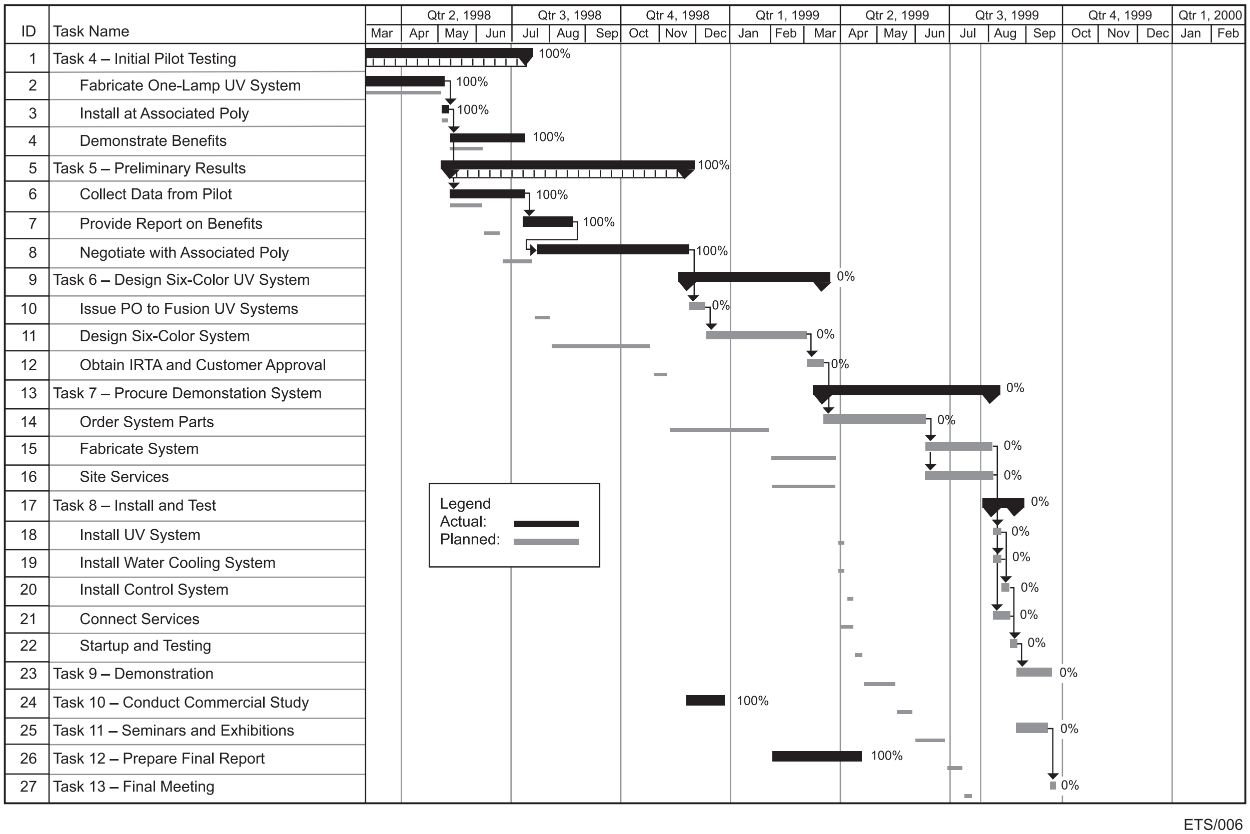

Figure 3. Proposed Program Schedule

1.5.2 Project Expenditures

The total cost of this project was estimated to be $500,000. A PIER Transition Program grant of $250,000 was approved by the California Energy Commission to support the program. The remaining program costs of $250,000 were to be contributed by SCE and equipment and supply vendors.

The one-color demonstration program was completed with SCE and PIER funding. Phase III was not initiated because the participating customer was unable to provide the funding necessary to proceed with the six-color retrofit, and the project schedule did not allow sufficient time to obtain the needed funds from other sources. However, the project team determined that sufficient production data had been collected and analyzed during Phase II to confidently project the costs and associated revenue likely to result from a full six-color production scenario. Consequently, only about $35,000 of the PIER funds had been expended when the project was halted in July 1999.

Figure 4 compares actual PIER fund expenditures to those projected.

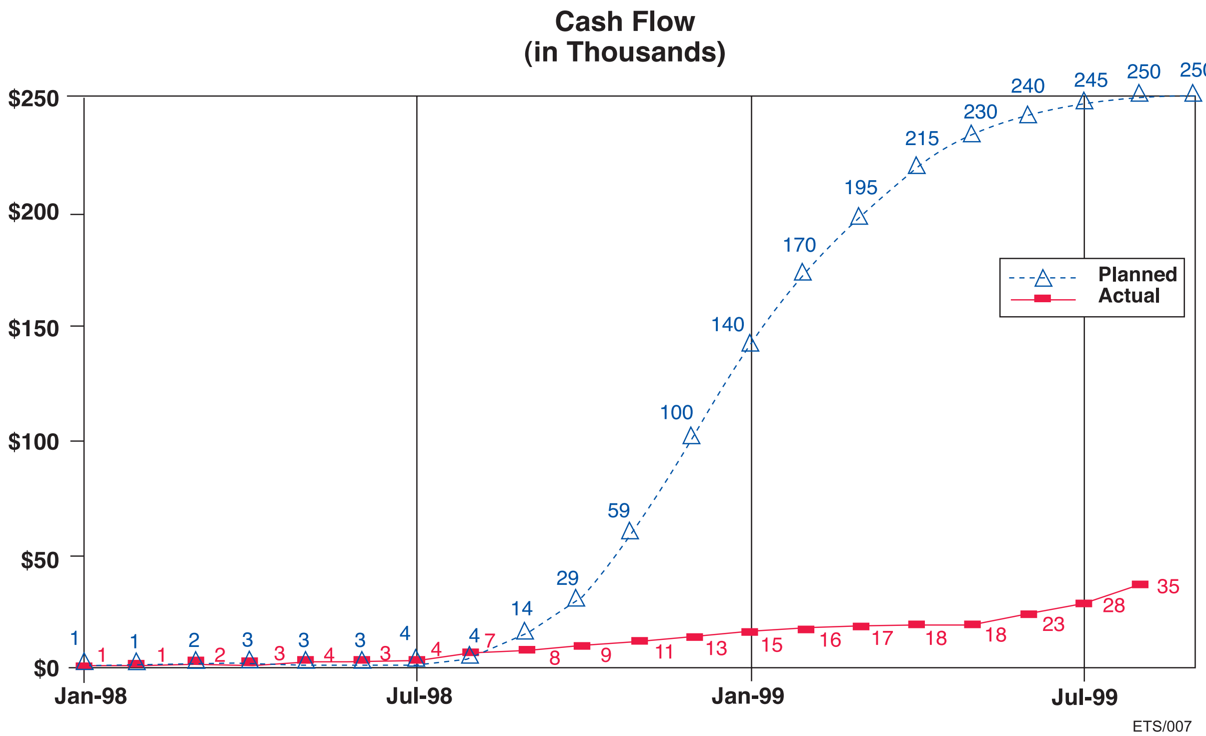

Figure 4. Commission Funded Expenditures – Projected versus Actual

1.6 Commercialization Potential

Clearly, UV-curable ink printing systems have many advantages, including improved product quality, lower labor requirements, reduction in equipment downtime, improved product consistency, and reduction in hazardous chemical use. There are some drawbacks, including high initial investment costs, higher ink costs, phase-in production costs, increased housekeeping requirements, and temperature control problems.

Printers who have already retrofitted their systems to use water-based inks may be reluctant to incur the additional expenses of retrofitting their systems to use UV technology. A detailed plan for commercialization of six-color technology is provided in Section 3.5 of this report. Although up front investment costs are high for UV-based systems, maintenance costs are lower. For this reason, the target market for commercialization is the potential new plastic bag printing press buyer.

1.7 Benefit to California

It is estimated that between 20 and 30 flexographic bag printers within the State are positioned to gain full benefit from retrofitting existing six-color presses to use UV-curable inks. Full benefit is defined as the ability to sell the additional product that would result from increased line speeds, and realize the projected savings associated with lower operating costs. The combined public and private benefits associated with commercialization are estimated to be approximately between $1.58 million and $6.32 million over a 10-year period. UV technology, therefore, has the potential to improve the competitiveness of commercial printing operations in the SCAQMD. Further, it improves air quality by reducing or even eliminating VOC emissions.

2.0 Project Description

2.1 Background

Edison Technology Solutions (ETS) and SCE, both affiliates of Edison International, recognized the importance of maintaining a viable and robust printing industry within the region. ETS was also impressed with the rapidly expanding market for materials produced by flexographic printing technology. ETS project investigators were keenly aware that foreign suppliers were not only an important influence in the local market but were already meeting much of the region's printing demand and were anxious to expand their share even further.

As a result, ETS proposed to evaluate the feasibility of retrofitting wide-web, plastic film flexographic printing presses to use ultraviolet (UV)-curable ink technology. The project was structured to compare the economic and productivity characteristics of UV-curable technology to other technologies (water-based ink or solvent-based ink with volatile organic compound (VOC) controls) capable of meeting Rule 1130 – Graphic Arts emission limitations.

2.1.1 Flexography

Flexography is a form of rotary web letterpress printing that uses flexible rubber or photopolymer plates and fast-drying solvent or water-based inks fed from an anilox inking system. The rubber plates are mounted to the printing cylinder with adhesives or by mechanical means and inked by ceramic-coated anilox rolls that have laser-engraved cells that serve as ink reservoirs.

The packaging industry is a major user of flexography printing technology, as most of the materials used by this industry consist of cellophane, plastics, metallic films, and corrugated fiber products. The flexographic printing technique can be used to print on virtually any material that will physically pass through the press. The majority of paper, corrugated fiber, and metallic film printers in the South Coast Air Basin (SCAB) have already converted their processes to use UV-curable inks.

In the last decade, the use of flexographic printing technology has grown at the rate of almost 8 percent each year. This rate is unparalleled by any other printing technology. Although some flexography application growth can be attributed to a growing demand for packaging, the technology is increasingly being used in markets traditionally served by gravure and offset lithography printing processes.

The term flexography was first introduced in 1952 and was formerly known as aniline printing. Flexography is a product of letterpress and is essentially direct rotary printing using flexible raised image printing plates and rapid drying fluid inks. The plates are made from rubber or photopolymer and the image is raised as in a conventional letterpress. (Refer to Appendix I, *An Initial Analysis of UV-Curable Inks for the Plastic Bag Printing Industry*.)

Flexographic printing units consist of three basic types: the two-roll unit, the two-roll unit with a doctor blade, and the dual-doctor ink chamber system. The wide web presses, most commonly used for printing on plastic substrates, use the dual-doctor ink chamber system (Figure 5).

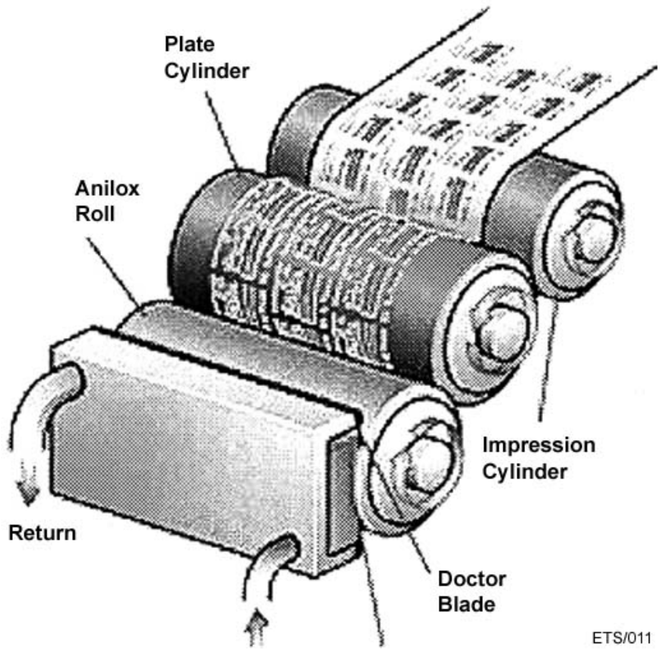

Figure 5. Flexographic Ink Delivery System

Most flexographic presses are web-fed and capable of printing four-color or six-color work on a continuous stream of substrate (the surface receiving the image). Ink is applied to the plate by a metal roller commonly known as the anilox roller. Bag printing is usually done on wide-web presses.

The anilox roll is engraved with a pattern of tiny cells so small they can only be seen under magnification. The size and number of these cells determine how much ink is delivered to the image areas of the plate, and ultimately to the substrate. Anilox rolls are commonly made either of copper that has been engraved and then chrome-plated, or of ceramic-coated steel with a laser-engraved cell surface, and they are quite expensive. They are carefully selected for specific types of printing, substrates, and product requirements.

If the engraved surfaces of a roll become clogged, the roll must be carefully cleaned. Often, cleaning requires the use of chemical solvents and removal of the roll from the press. As a result, the operator is required to maintain an inventory of spare rolls or experience lost production time when rolls become clogged.

2.1.2 Regulatory Impact

Rule 1130 was originally adopted in 1980 and has been amended several times since. As part of the 1995 amendments, SCAQMD staff performed a technology assessment to determine the appropriate controls for the industry. The District concluded that a number of facilities were successfully using water-based inks and the Rule was ultimately adopted to reflect this position. The Rule now requires flexographic bag printers to use inks with a VOC content of 300 grams per liter or less or to adopt add-on controls. (Reference: Lents, James M., Ph.D., *Staff Report, Feasibility of Using Rule 1130 – Graphic Arts – Compliant Inks in the Flexographic Printing of Polyethylene and Polypropylene Bags*, AQMD Board Agenda, Item #23, January 12, 1996.) The overall capture and control efficiency of the controls must be at least 67 percent, which would reduce emissions to a level equal to or lower than that which would be achieved through adoption of the 300 gram-per-liter inks.

Nevertheless, the substitute inks, particularly the water-based inks, have not proven to be attractive alternatives to the VOC-rich solvent-based inks used in the past. In addition to experiencing reduced production throughputs, caused by lengthened drying time requirements, operators have complained that water-based inks do not produce print quality results comparable to those previously realized using solvent-based inks. Some operators claim to have lost customers because of the poor product quality obtained from water-based inks.

The economic burdens imposed by Rule 1130 have forced some printers to abandon the business altogether and others to relocate to areas with less stringent control requirements. Moreover, those that are left are at a competitive disadvantage to operators situated in locales with less stringent VOC emission regulations.

2.1.3 Properties of Printing Inks

Inks may have many ingredients, but fundamentally ink includes components that provide color (pigment, dye, or colorant) and a liquid base (solvent) that suspends the pigment and provides a means of transportation from the ink fountain to the substrate. Other components and additives are included in the ink formulation to control the ink distribution process, fix the pigment onto the substrate, and enhance specific characteristics of the printed image.

Figure 6 shows the composition of traditional flexographic inks. (Reference: Lawler International, Inc., A *Look at the Four Most Widely Used Printing Processes*, http://www.lawler.com/page 15.html.)

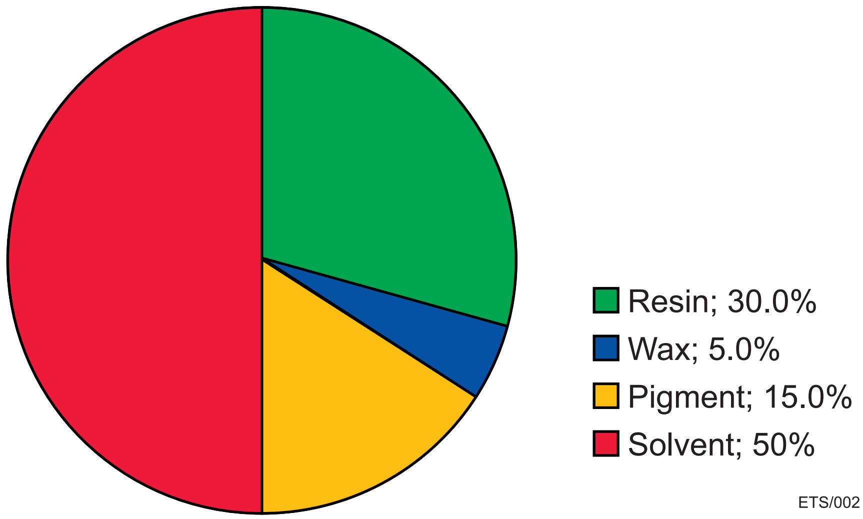

Figure 6. Traditional Flexographic Ink Composition

When printing with traditional water- and solvent-based inks, dryers are used to apply heat to the web. The heat is used to accelerate the evaporative process, which removes about 35 to 40 percent of the ink volume delivered to the printed surface. In other words, it is necessary to deliver up to 40 percent more volume to the substrate with water- or solvent-based ink than that necessary to achieve the desired color density alone.

Solvent-based inks have been popular for many years and provide excellent results on non-absorbent web surfaces such as poly films. However, the most widely used printing solvents include VOCs and are derived from petroleum or alcohol bases.

VOCs in their gaseous or evaporative state can react with other atmospheric chemicals to produce adverse air quality effects. These printing solvents can suspend fine particulate matter in a gaseous state easily inhaled by nearby workers. This can be deposited deep within lung tissue, which can be detrimental to their health.

Growing concerns for improved ambient air quality and maintenance of workplace health standards have contributed to the search for more benign printing products and processes. Many printers have attempted to use inks that use water or soy bean oil as solvents.

Water-based inks tend to be more difficult to work with on film substrates and they tend to smudge and smear easily. Moreover, water-based ink can dry in the cell structure of the application roll, thereby reducing available cell volume. When this occurs, laydown rates are impacted and print uniformity can be adversely affected. It then becomes necessary to remove the roll from the press for cleaning, an activity that can require the use of fine abrasives (potential particulate inhalant) or powerful industrial cleaners.

The color selection for soy-based inks is limited and these inks require extended drying times. They also tend to smudge and smear.

2.1.4 Technology and Regulation

SCAQMD rulemaking is intended to drive technology. That is, the District's rulemaking requires the use of Best Available Control Technologies (BACT) for the issuance of its permits. If, when fully implemented, BACT is inadequate to meet allowable emission values for the Basin, requirements may be established that can only be met by new technology and/or production practices.

For the technology assessment leading up to the adoption of Rule 1130, District technical staff visited 18 flexographic printing facilities. Some of these firms were then using 1.1.1-trichloroethane (TCA)-based inks. TCA has since been banned from production and the chemical, while still available, is extremely expensive. Although the chemical at one time was found in many inks used by the flexographic printing trade, it is no longer used.

Several of the facilities visited by District staff had converted to the use of water-borne inks and some were operating under variances from Rule 1130. Since then, most firms have either converted to water-borne ink systems or purchased a control device.

Control devices are expensive to purchase and operate. Moreover, there is no guarantee that the device purchased today will meet future District requirements, which are likely to become more stringent. The early experience with water-borne inks has not been universally positive. Some firms think the inks contribute to a poor product. Others have experienced reduced production, attributable to added drying requirements, longer setup times, and special handling for anilox rollers.

UV-curable inks are now available for the flexographic printing trade. These inks contain no VOCs and can be used without control devices. Moreover, the use of UV-curable inks ensures compliance with future District VOC limitations, even if they become more stringent.

2.1.5 Emerging Ink and Printing Technology

In the mid- to late-1980s, flexographic paper printers began ordering presses equipped to use UV-curing technology. Currently, about 15 to 20 percent of the new paper printing presses sold nationwide are fully equipped for UV. Moreover, many older presses are being modified to take advantage of this technology, which produces printed and coated materials of high quality while still meeting the requirements of Rule 1130.

To date, most of the press retrofits to UV-curable technology within the SCAB have involved the so-called narrow web presses that are used to print on paper, plastic, and metallic substrates. However, none of the wide-web presses used by bag printers have been retrofitted to fully use UV-curable ink technology.

Since UV inks do not dry in the air, they do not tend to plug the cells. There is no ink component that evaporates, so there is no need for cleanups between press runs. The press could even be left over the weekend without cleaning and be ready to go on Monday.

UV inks act like liquid plastic. As the ink is exposed to specific wavelengths of concentrated UV radiation, a chemical reaction takes place during which the photo initiators cause the ink components to cross-link into a solid. Since no material is removed, nearly 100 percent of the delivered volume is used to provide coloration.

Assuming all of the ink is transferred from the cells to the substrate to attain the color density previously attained with water-based ink, the anilox roll would have to be specified to deliver about 35 percent less ink to the substrate. Of course, viscosity plays a key role in determining the percentage of ink to transfer (transfer factor).

2.2 Promised Benefits

The use of UV-curable inks appear to offer many benefits, including the following:

- **Improved Product Quality** – Because 100 percent of the material applied to the substrate remains after curing, there is the potential to achieve greater densities than with conventional inks. Due to the higher viscosities, UV inks tend to stay where they are placed. Dot gain is negligible, resulting in exceptional image sharpness. For that reason, UV inks work well for process printing for five lines and vignettes.
- **Improved Product Durability –** Cured UV ink provides many desirable end-use qualities including excellent rub resistance and chemical resistance, exceptional color consistency, and superior gloss. Depending on the pigment, UV inks also provide lightfastness and opacity.
- **Lower Labor Requirements –** UV inks come press-ready. Consequently, setup times are reduced and less waste is generated. Another advantage of UV inks is that operator involvement is reduced. There is less variability from operator to operator and press run to press run because the ink consistency is not manipulated at press side. (Reference: Lanska, David, *Stork Sheds Light on UV Inks*, Stork Celleramic, http://www.cellramic.storkgroup.com.)
- **Reduced Equipment Downtime –** One of the greatest advantages of UV inks is that they do not change consistency or color strength due to evaporation or pH. Without manipulation, the ink maintains consistency for the duration of a press run. UV inks provide additional benefits because the ink does not dry in the cells. Significant savings can be realized for labor, consumables, anilox roll cleaning expenses, and roll refurbishment.
- **Improved Product Consistency –** With typical water- and solvent-based inks, evaporation results in variability. Over time, the ink changes viscosity and affects laydown. Ink resins dry in the cells of the anilox roll, resulting in further changes to the laydown. Press operators, attempting to correct for changes in ink density, add extenders and other additives to the ink. Degradation of the print quality results as the anilox roll becomes plugged. The ink is further altered until its consistency has little resemblance to the ink used at the beginning of the job.
- **Reduced Need for Hazardous Chemical Use –** Because of the tendency of water-based inks to plug the anilox rolls, it is necessary to pay extremely careful attention to press-side housekeeping practices. Rolls will begin to plug while running due to evaporation and heat generated by friction from the doctor blade or plate contact (see Figure 5).

When this happens, the rolls must be removed from the press and cleaned with aggressive chemicals or harsh agitation action, either of which can damage the fragile engraved cell structure.

2.3 Printer Concerns

Despite the promised benefits, plastic sheet printers are not convinced that UV-curable ink printing will work for their application. There are many unanswered concerns on the effect on the substrate, poor adhesion, speed of printing, and the overall economic viability of UV printing on plastic sheets. The following summarizes some printer concerns:

- **High Initial Investment Costs** – While maintenance costs and losses due to waste are significantly lower for UV flexographic systems, retrofit costs are considerable. Retrofits of existing six-color presses can cost from $250,000 to $400,000. While this cost is favorably comparable to conversion of a solvent-borne press to use water-borne inks, it is not one that is attractive for a press that has already been converted for water-borne ink use.
- **Additional Materials Costs** – UV inks are perceived to be expensive at approximately $10.00 per pound. This translates to approximately 2.2 cents per printed foot compared to approximately 1.65 cents per printed foot for water-based inks. Moreover, UV-curable inks are not manipulable. Therefore, print color must be adjusted by the use of different anilox rolls. This requires the operator to keep a larger inventory of anilox rolls on hand and to more precisely specify roll cell specifications for a given print job.
- **Additional Operating Costs and Requirements** – UV inks require special lamps that focus UV energy onto the web surface. The purchase of the lamps represents a significant up front capital cost. Cooling systems are required to dissipate some of the heat from the lamps. The electrical energy requirement for cooling and the UV lamps is usually greater than for either water-borne ink systems or solvent-borne systems with emission controls.
- **Phase-In Production Loss** – Switching to a new system generally results in expenses, errors, and waste until the system is well understood and all parameters are fine-tuned.
- **Necessity for Attentive Housekeeping Practices** – Because UV inks do not dry, any small spill can result in a large mess. Ink can be tracked from department to department on shoes. UV ink can damage clothes and irritate the skin. A few press operators have been known to experience allergic reactions to UV ink chemistry. Care must always be taken to prevent direct contact with the skin.
- **Application Limitations** – UV inks do not adhere well to some poly substrates. To elevate the surface tension enough to achieve good adhesion, some substrates require that the printing surface be pretreated. It should be noted that this additional setup task is also frequently required for water-borne ink systems.
- **Equipment Damage and Temperature Control** – The UV curing mechanism also produces a significant amount of heat that provides no benefit to the curing process and actually produces a negative effect by inducing heat onto the printing drum. Drum expansion can cause the print and process dot size to expand and send the press out of registration. Unwanted heat can also damage the web surface. During idle cycles, webs

have been scorched and broken. This problem is addressed by the routine addition of a chiller unit for new and retrofitted presses, which places an additional energy demand on the total press system.

2.4 Program Phases

The program was divided into three phases.

2.4.1 Phase I – Conduct Comparative Study of Flexographic Printing Technologies

Phase I of the program, which was fully funded by SCE, included:

- A preliminary technology investigation
- A preliminary assessment of target market attitudes
- Identification of equipment and supply vendors
- Preliminary cost estimates for the demonstration phase.

Phase I of the program was initiated in July of 1997. The Institute for Research and Technical Assistance (IRTA), under contract to SCE, had primary responsibility for conducting this phase of the program.

IRTA conducted interviews with active print operators to determine attitudes and process priorities that would affect market acceptability of the process. IRTA also developed a report entitled, *An Initial Analysis of UV-Curable Inks for the Plastic Bag Printing Industry* (Appendix I) and provided estimates to adopt UV technology, entitled, *Cost Comparison for Bag Printing Operations* (Appendix II). The estimates were based on several scenarios, ranging from retrofit of existing equipment to the purchase of brand new presses.

Operational cost estimates compared the cost of using solvent-borne, water-borne, and UV-curable inks. All scenarios were prepared for flexographic applications printing on plastic substrates (Table 2 and Figure 7).

Table 2. Annualized Cost of Retrofit System Alternatives

Cost Center	Water-Based Inks	UV-Curable Inks	Solvent With Controls
Annualized Capital	$18,625	$35,905	$55,125
Ink	$190,740	$254,320	$216,866
Gas	$17,152	$0	$50,749
Electricity	$36,336	$73,430	$57,020
Maintenance	$96,115	$14,285	$30,083
Reject – Loss	$155,520	$8,324	$18,918
Total	$514,488	$386,264	$428,761

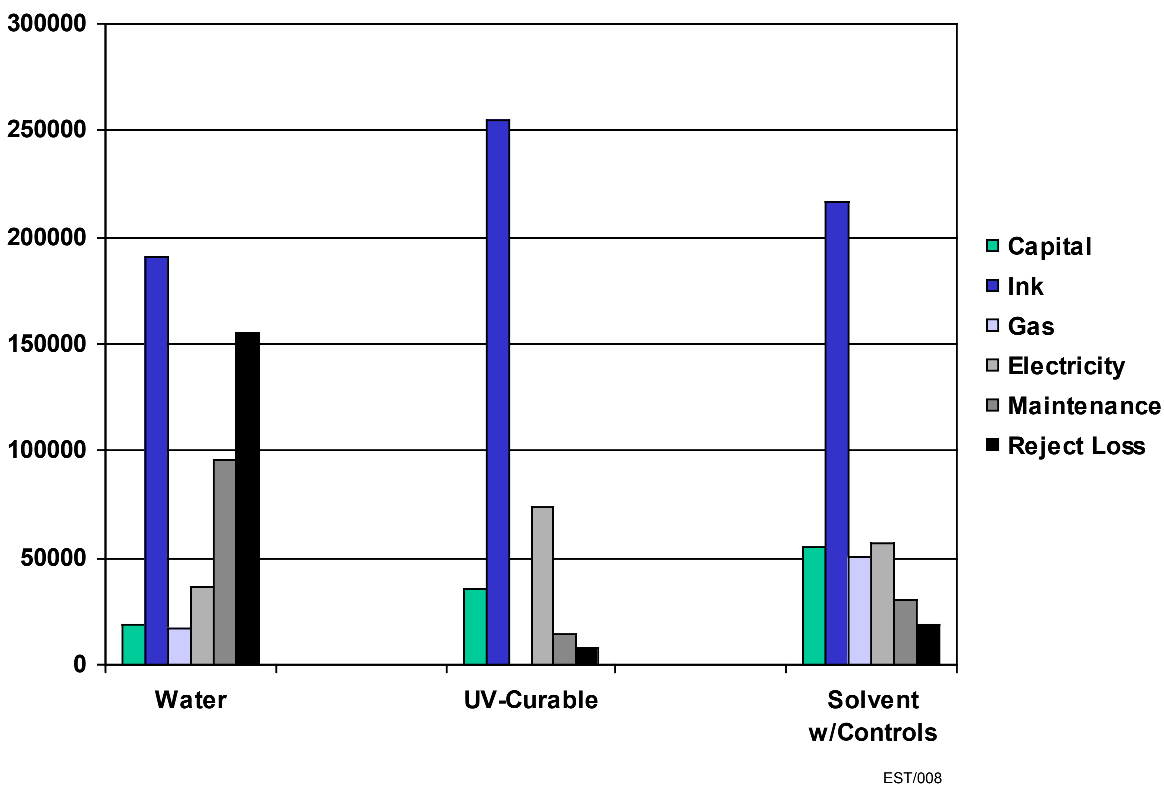

Figure 7. Comparative Annualized Costs by Technology

Finally, the report made recommendations for a demonstration of the technology in a bag printing facility.

2.4.2 Phase II – Demonstrate One-Color UV Printing on Plastics

Phase II of the program, which was fully funded by California Energy Commission, was divided into four tasks designed to test and demonstrate the operational feasibility of UV-curable technology using a one-color prototypical pilot line. This phase began in October 1997 and included the following activities:

- Identification of participating customer, UV ink supplier, and equipment vendor
- Engineering, design, and installation of pilot one-color system
- Testing and production simulation of the prototypical one-color system
- Preparation of pilot test results.

The program's Phase III, pilot test demonstration of a six-color system, was not undertaken because the participating customer was unable to meet his cost-sharing obligations in time to meet the project's scheduling requirements.

2.4.2.1 Participating Customer, UV Ink Supplier, and Equipment Vendor

Several paper printers within the Basin have demonstrated the use of UV-curable inks for flexographic printing applications. Based upon this evidence and the experience of other printers reported in industry publications, the IRTA preliminary study determined that this technology was feasible for bag printing operations.

The IRTA preliminary investigation included an assessment of target market attitudes. These investigations revealed significant dissatisfaction with product results obtained from the use of water-borne inks. Printers expressed concern that the poor quality of finished products, in which water-borne inks were used, was responsible for the loss of some customers.

After completion of a search for interested ink and equipment vendors, Sun Chemicals was selected to supply inks. Fusion UV was selected to provide and install the UV curing system.

Interviews with Associated Poly Bag Corporation during the early stages of the program demonstrated the firm's interest in participating in Phase II of the program. This interest was primarily driven by dissatisfaction with the print quality produced by a recently retrofitted water-based ink press.

Associated Poly also expressed a willingness to share the cost of retrofitting one of their six-color presses for Phase III, if the technical feasibility of the UV-curable system was verified in Phase II. The firm's two, six-color presses are of a type most commonly used in the Basin and one was particularly well suited for a retrofit at a reasonable cost. Based on these considerations, Associated Poly was selected to be the demonstration site for this project.

Contracts were signed with Fusion UV to provide the UV curing equipment, and with Sun Chemicals to supply the UV-curable inks. Fusion UV is a member of RadTech, a trade organization that fosters the increased use of UV technologies. Fusion UV has been active in developing new applications within the printing industry for UV-curable technology. Fusion UV indicated a willingness to share in the cost of the six-color UV system demonstration, and to provide the equipment for the one-color UV printing pilot test free of charge.

Sun Chemicals was identified as the UV-curable ink supplier. They were selected because of their previous involvement with Fusion UV on similar demonstration projects, and for their interest in this project. Sun Chemicals has a strong local presence in Southern California, and committed to lend support from their national office.

As explained earlier, Associated Poly was selected to be the demonstration site. Associated Poly agreed to dedicate one of their presses for the one-color UV system test. They also agreed to provide labor and substrate material required for the test free of charge.

2.4.2.2 Engineering Design and Installation of One-Color System

This task included a field assessment of the demonstration site by Fusion UV technicians. The equipment to be used was inspected and plans were developed to retrofit the press that was used for the one-color demonstration test.

Fusion UV installed a single-lamp system together with the ancillary monitoring and control system.

The one-color system did not require a chiller system, which would normally be required for commercial continuous operation to dissipate the heat generated by multiple UV lamps. In lieu of a chiller, a water cooling system was used for the one-color UV system test.

Figure 8shows the installation of a single-lamp UV system at the Associated Poly site.

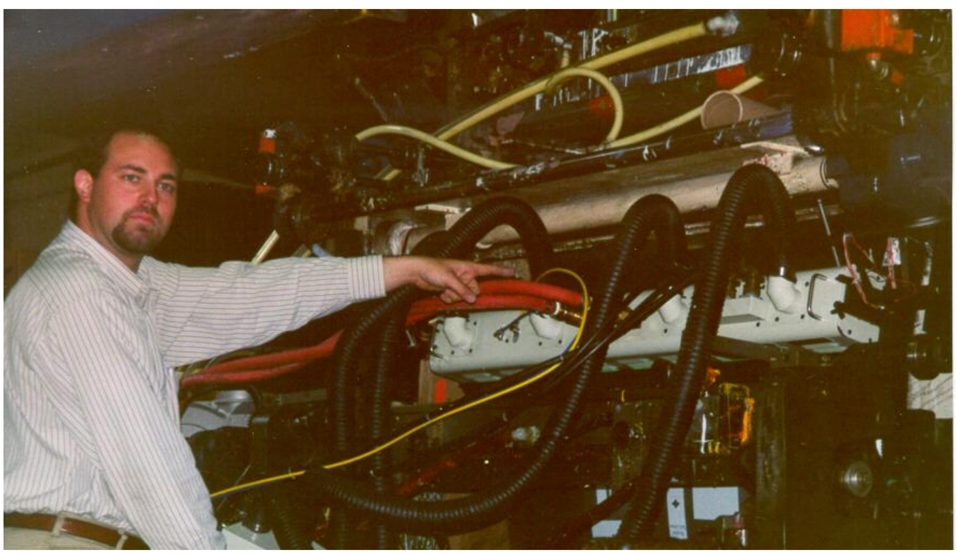

Figure 8. Installing Single-Lamp UV System at Associated Poly Bag Corporation

Figure 9 is a close-up view of the UV lamp installed on the Associated Poly one-color press. Note the lamp power and cooling lines.

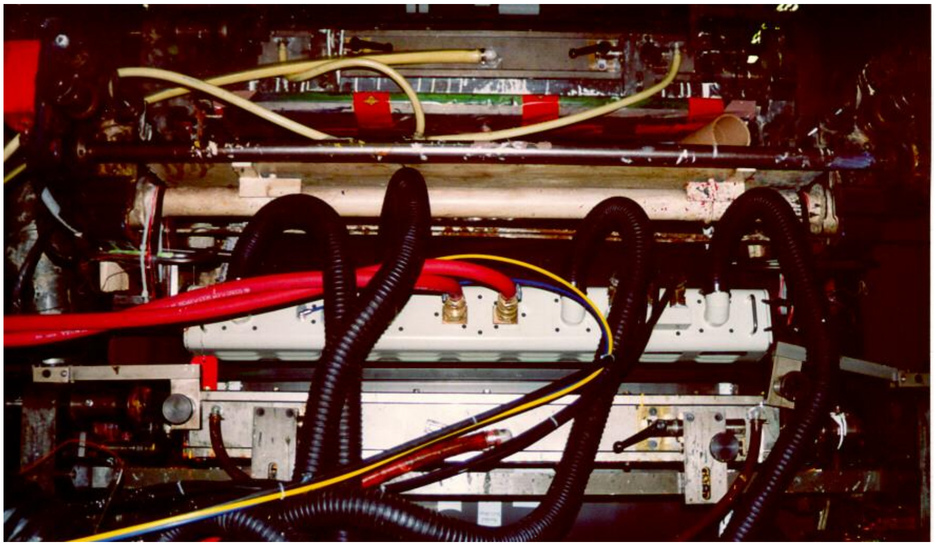

Figure 9. Installed UV Lamp Close-up

UV curing involves a photopolymer chemical reaction that almost instantly converts liquid chemicals into a solid when exposed to photons of high-intensity UV light. The lamp module is the portion of the system that emits light to which the chemicals are directly exposed. The lamp module consists of the UV lamp, reflector, and cooling system. In full production applications, a chiller unit is most often used but, for the Associated Poly demonstration, a standalone water cooling system was used.

The remaining portions of the Associated Poly demonstration system included a power supply and control panel. Figure 10 shows these skid-mounted units as they were installed for Phase II one-color pilot-line testing.

Figure 10. Ancillary Units at Associated Poly Bag Pilot Test

2.4.2.3 Testing and Production Simulation of the Prototypical One-Color System

System startup took place on May 8, 1998. Within 3 hours, satisfactory results had been obtained from the shakedown checklist, and the press was running at 750 feet per minute in simulated production mode. The production rate was two to three times faster than the best speeds obtained from the press over the last 2 years using water-based inks.

Associated Poly's operator and the Fusion UV technician agreed the system was running properly, and full production mode pilot testing, using real print jobs, began the following day. Fusion UV technicians observed production onsite for another two days during which the test press operated without incident. IRTA staff continued to measure line speed, feet processed, and ink usage and to conduct tests of print quality including adhesion, wet rubbing, and scuff resistance for different types of ink and substrate material.

The one-color production test was successfully conducted over a period of 2 months. IRTA collected adequate data to determine average cost of ink per printed foot, reject loss, and time needed to conduct routine maintenance. The test data was used to fine tune the equipment and identify the type of UV ink that achieves optimal economical operation of the UV system.

Appendix III, *One-Color Pilot Test Results*, the IRTA July 1998 report, contains the pilot testing results, and projects detailed costs for a six-color UV system based on the single-color pilot testing results. Scenarios were developed for full and constrained market assumptions for both Associated Poly and a typical Southern California printer.

Figure 11 compares the income potential for UV-curable ink presses with water-borne and solvent-based inks with controls. This analysis uses the full-production scenarios, which assume that the printer will be able to sell all of the additional product that would derive from increased press speeds (from 300 feet per minute to 600 feet per minute) made possible by the UV curing system.

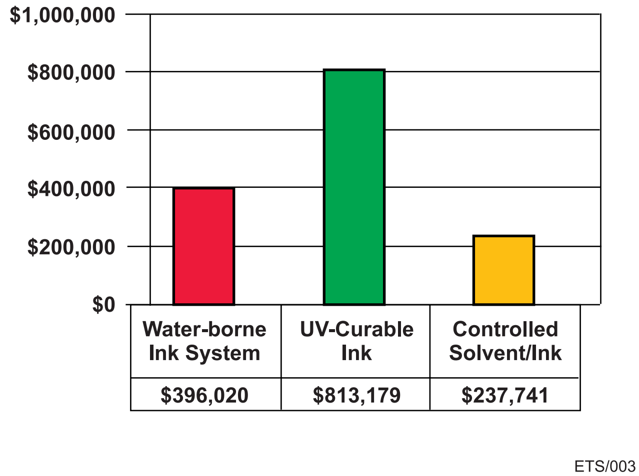

Figure 11. Net Income Projection

The constrained market scenario (fixed production) is based on the assumption that current market demand is being met; however, the market will expand slightly in a pattern consistent with historic market growth. Overall, the analysis concluded that UV printing technology would provide superior profit under each of the analyzed scenarios. The greatest profit advantage would be realized if the printer were able to fully use the increased speed of the UV printing process. At 600 feet per minute versus the normal 300 feet per minute press speed for water-based ink, the incremental benefits to Associated Poly would be almost $500,000 per year.

It should be noted that the full-production scenario market assumption might not be realistic. There is no particular market advantage gained from geography in the printing of packaging materials. Out-of-basin operators, in adjacent states and foreign countries, are currently a competitive presence in the local market. Consequently, Associated Poly did not find this economic incentive to be particularly persuasive because the firm was not confident the additional production associated with the full-press speed scenario could be sold. Therefore, Associated Poly considers the fixed production scenario, at present-day sales levels, to be the base scenario for calculating the benefits they are likely to achieve from retrofitting a six-color, six-lamp press to use UV-curable inks.

2.5 Problems Encountered

2.5.1 Start Up Delay

Unforeseen circumstances delayed shipment of the Fusion UV equipment by almost 3 months until May 4, 1998. Once on site, the system was installed on an Associated Poly press in 3 days. Most of this time was spent hooking up the unique monitors for the test, and would not normally be required for a commercial setup.

2.5.2 Inadequate Cost-Share Funding

As stated earlier, each phase of this program was planned to begin when proceeding phases returned expected or encouraging results. Phase II, the Single-Color Production Test, was an unqualified success and provided adequate economic and technological encouragement to proceed with Phase III, the Six-Color Production Demonstration.

Based on Phase II results, it was estimated that a typical six-color plastic bag print operation, converted from water-based inks to UV technology, would increase income by almost $100,000 annually, assuming no increase in sales, because of the reduced operating costs.

The equipment used to demonstrate the UV technology during Phase II was returned to Fusion UV, the technology partner. The estimated cost to retrofit Associated Poly's six-color press was $349,470. Based upon available funding, approximately $109,470 in additional funding was needed to proceed to Phase III.

ETS recommended changes to the program plan while it solicited the funds needed to proceed with the project. However, it was decided the project could not complete the six-color demonstration before the PIER funding deadline of September 1999, even if the deficit funding was secured. As a result, ETS terminated the project and Phase III was not undertaken.

3.0 Conclusions and Recommendations

Flexographic print-on-plastic operations using UV-curable inks and curing lamps exhibit superior print quality products when compared to water-borne ink technology. Further, they exhibit superior productivity characteristics compared to water-borne and solvent-borne systems. Annualized costs for retrofitted UV flexographic systems are significantly lower than to retrofit solvent-based systems to use water-based inks or install suitable emissions controls. Up front capital outlays to retrofit water-borne or solvent-borne systems to use UV curable inks are considerable and present a major barrier to penetration of this segment of the market. Income projections, including allowances for debt service, show positive results under both fixed- and full-production scenarios. The local bag printing industry is sensitive to technology forcing regulation; however, most South Coast Air Basin (SCAB) bag printers have met current regulations through investment in water-borne ink systems. Further, printers who use water-borne inks are not likely to make the significant investment required to retrofit existing presses. Commercialization efforts should, therefore, target potential purchasers of new systems.

3.1 Program Objectives

The objective of this program was to collect and analyze sufficient operational and productivity data to demonstrate the feasibility of using UV-cured printing technology to print on plastic films using wide-web flexographic printing techniques. The plan was to initially demonstrate these operational and environmental benefits on a one-color system, and use lessons learned to improve and demonstrate the technology on a six-color system.

Specifically the objectives were to determine:

- Verify compliance with SCAQMD Rule 1130 – Graphic Arts, by reducing or eliminating the use of volatile organic compound (VOC) solvents.
- Match or exceed the print quality of solvent-based ink systems with emission controls, or of water-based ink systems.
- Reduce process time requirements.
- Reduce process energy usage.
- Reduce maintenance costs.

3.2 Program Outcomes

Phase I of this program clearly demonstrated the economic and productivity advantages of using UV-curable inks to meet the air quality objectives of SCAQMD Rule 1130 – Graphic Arts. The advantages were impressive for both new equipment purchase and existing equipment retrofit scenarios. Moreover, the use of this technology was economically feasible under either unconstrained or constrained market conditions.

Phase II verified the projections prepared during Phase I using a customer-owned one-color press as a production test bed. The production simulation phase was an unqualified success.

For the one-color system, the project demonstrated:

- Full compliance with current (SCAQMD Rule 1130) by eliminating the use of VOC solvents. Since UV-curable technology eliminates VOC emissions, it offers protection against further rule changes. In addition, the elimination of airborne vapors, particularly ammonia and fine particulates, improves the workplace environment

- Higher product quality when compared to water-based ink systems, and equal product quality when compared to solvent-based ink systems. Reject rates were reduced to 1 to 3 percent, compared to 10 to 15 percent for water-based ink systems.
- Production rates more than double the best rates achieved by water-based ink systems. These reductions are due to the elimination of ink drying requirements needed for solvent- or water-based inks.
- Reduction of energy use by 75 percent, and energy cost by 50 percent. These savings are due the elimination of ink drying, and the elimination of the need for emission control equipment.
- Maintenance costs were reduced because UV-cured ink stays liquid between runs and shifts, as long as it is not exposed to UV light. This eliminates clogging and damage to the press equipment common with other types of ink.

It was not possible to demonstrate the six-color system because of budget and time constraints. Associated Poly was unable to meet cost-sharing obligations in a timely manner. The very tight project schedule made it difficult to secure the funding needed from other sources to retrofit a six-color press for Phase III demonstration and analysis. It was agreed that sufficient information had been obtained to verify the feasibility of the technology without the need to demonstrate the six-color UV printing system. Moreover, it was concluded that such a decision would not adversely impact the commercialization chances of this environmentally clean technology. In addition to the outcomes derived from the one-color test, the full- production scenario analysis identified two additional benefits: lower annualized costs; and higher income potential in full-production scenarios in which the printer sells all additional product derived from increased press speeds.

3.3 Commercialization Constraints

With the passage of Rule 1130 – Graphic Arts, most of the Basin flexographic printers had four options: add VOC emission controls; retrofit their solvent-ink presses to water-borne systems; retrofit their solvent-ink presses to use UV-curable inks; or move out of the Basin.

Most of the Basin bag printers retrofitted their wide-web presses to water-borne systems; however, many experienced significant problems with this technology. Some of these problems were attributable to inexperience with the peculiarities of water-borne systems and, over time, operators have learned to consistently produce an acceptable product.

Retrofit costs for solvent-ink system presses are considerable and about the same for conversion to water-based or UV-curable ink systems. The installation of emission controls is also significant, and operators who have made the investment to convert to water-borne systems are likely to be reluctant to finance a second retrofit to UV-curable ink systems in the absence of a very significant economic advantage or increased regulatory pressure.

Another damper on conversion enthusiasm is the cost of ink. Even though UV-curable inks have been shown to produce superior quality and print mileage results, the current cost of UV inks is almost twice that of water-borne inks. It is expected that prices will decline as demand for UV-curable ink increases. However, for the present, the cost of UV ink is perceived to be high.

3.4 California Benefits Potential

It is estimated that between 20 and 30 flexographic bag printers within the State are positioned to derive full benefit from retrofitting existing six-color presses to use UV-curable inks. Full benefit is defined as the ability to sell all additional product that would result from increased line speeds, and realize the projected savings associated with lower operating costs.

Table 3 details the assumptions made for the low case and high case for the California benefits calculation. The low case assumes the total number of printers that would benefit from UV printing is 20, while the high case assumes 30. Most of the printers have two presses, but the low case assumes one press per printer. Although the economic benefits of UV printing are clear, the low case scenario assumes 25 percent market penetration, while the high case is 44 percent. Accordingly, all of the following California benefits calculations assume five presses will be converted for the low case scenario, and 20 for the high case.

Table 3. Benefit Calculation Assumptions

Benefit Calculation Assumptions	Low Case	High Case
Potential Plastic Bag Printer Customers	20	30
Average Presses Per Printer	1	1.5
Total Number of Presses	20	45
Market Penetration of UV Printing	25%	44%
Expected Number of Presses Converted to UV	5	20

Table 4 shows the private and public benefits for each case.

Table 4. Annual Economic Benefit Projection

Annual Economic Benefit Estimate	Per Press	Low Case (5 Presses)	High Case (20 Presses)
Private Benefits			
Expected California Private Benefits	$250,000	$1,250,000	$5,000,000
Public Benefits			
Extra Sales from Additional Production Speeds of UV	$176,667	$883,335	$3,533,340
Extra Average 7.75% California Tax Due to Increased Sales of California Printed Plastic Bags	$13,692	$68,458	$273,833

Assuming a $250,000 operating cost savings per press per year (associated with UV technology), private benefits would extend from approximately $1.25 million, for the low case scenario (five presses), to approximately $5 million annually for the high case scenario (20 presses). Market penetration of the UV technology within the plastic bag printing industry is not expected to generate any additional jobs. However, approximately $68,500 (low penetration scenario) and $273,833 (high penetration scenario) in additional annual sales tax revenues would flow from commercialization of this technology. Sales tax revenues are calculated as follows:

Low Case: $176,667 (extra sales per press) x 5 (presses) x 7.75% (sales tax) = $68,458.

High Case: $176,667 (extra sales per press) x 20 (presses) x 7.75% (sales tax) = $273,833.

Table 5 summarizes the environmental benefits derived from the adoption of the UV printing for the low and high cases. It specifies the reduction in energy use for each scenario. Energy efficiency is valued at $262,600 to $1,050,000 annually based on a $3 per million British Thermal Units (BTUs) cost of natural gas.

Table 5. Annual Environmental Benefits

Annual Environmental Benefit Estimate	Per Press	Low Case (5 Presses)	High Case (20 Presses)
Reduction in VOC Emissions		Regulatory Compliance Assumed for All Technologies – No Net Benefit	
Reduction in Energy Use Per Press		75%	75%
Total California Reduction in Energy Uses in Million BTU	17,500	87,500	350,000
Value of Energy Efficiency to California at $3/million BTU	$52,500	$262,500	$1,050,000

Table 6 summarizes the benefits to California and compares them to the California Energy Commission's (Commission) cost of supporting the program.

Table 6. Return-on-Investment Estimate

Net Present Value Calculation	Low Case	High Case
Total California Private and Public Benefits	$1,580,958	$6,323,833
Expected Number of Years to Full Market Penetration	3	2
Discount Rate	10%	10%
Probability of Success	30%	50%
California Energy Commission R&D Funding Level ($25,000 SCE + $25 California Energy Commission Transition + $500,000 Proposed + $50,000 California Energy Commission Project Manager Cost)	$600,000	$600,000
Net Present Value (NPV) of 10 Years Benefits after Full Penetration	$2,189,550	$16,056,702
California Benefit-to-Cost Ratio	3.6	30.1

The calculation takes into account a different number of years for market penetration and different probabilities of success for each scenario. This is in addition to the basic assumption that 5 presses will be converted for the low case scenario, while 20 presses will be converted for the high case scenario. The Commission's benefit-to-cost ratio will range from 3.6 for the low case, to more than 30 for the high case. Normally, a benefit-to-cost ratio of 2 should be adequate to justify research and development (R&D) funding. UV printing seems to have an excellent benefit-to-cost ratio that justifies continued Commission support of the technology.

3.5 Conclusions

The use of UV-curable technology for flexographic printing is gaining converts. The current cost for a new water-borne or UV-curable ink press is about the same and, given the superior income production capabilities of the UV-curable systems, most purchases of new flexographic presses should involve UV-curable technology.

The advantages were impressive for both new equipment purchase and existing equipment retrofit scenarios. Moreover, the technology was economically feasible under either unconstrained or constrained market conditions.

UV curing technology as an alternative to installation of emission control equipment or the use of non-VOC inks proved to be both attainable and commercially viable.

Demonstrated benefits include:

- Full compliance with SCAQMD Rule 1130.
- Higher product quality.
- Increased production rates.
- Reduced energy use by 75 percent and energy cost by 50 percent.
- Reduced maintenance costs.

3.6 Recommendations

The trend toward increased use of UV-curable technology should be encouraged through a technology transfer program that will put the results of this program in the hands of potential new press buyers. ETS recommends the Commission initiate a technology transfer program that provides this information to potential new press buyers

To reduce the current cost of UV-curable inks, research in new UV-curable ink formulations that are less expensive than those currently available should be pursued. Another perhaps more practical approach to cost reduction would be to increase the usage of these inks to realize unit cost reductions available through volume production.

ETS recommends that the Commission sponsor a six-color printing demonstration program to foster commercialization of UV technology. Following are the tasks required for the proposed program:

- **Task 1.0, Market Survey** – Since the passage of Rule 1130, Basin printers have adopted various strategies to achieve compliance. Some have added controls to old solvent-based systems, while others have retrofitted their presses to use water-based inks. Information is needed on how well each of these strategies have succeeded in meeting the needs of individual printers. Gather compliance and enforcement information from the SCAQMD, particularly from those facilities that opted to add controls to solvent-borne systems. Conduct interviews with each of the Basin's bag printers to determine their attitudes on their current compliance strategies.

- **Task 2.0, Technology Transfer Program** – Based upon the information gathered during Phases I and II of this program, design a comprehensive public information program to focus on printers' needs as determined by Task 1.0 above. Include wide and appropriate dissemination of the final report, conduct of technical seminars, and information distribution via the World Wide Web.
- **Task 3.0, Identify and Qualify Participating Customer** – Identify a potential customer to share in the cost and testing of a retrofitted six-color press. Ensure the potential customer is motivated and has the funds to meet the agreed financial arrangements.
- **Task 4.0, Design Six–Color UV System** – Prepare specifications, designs, and drawings for the six-color UV system. The contractor would use data obtained from the one-color pilot testing (Phase II) and the market survey (Task 1) to ensure the commercialization of the technology.
- **Task 5.0, Procure Demonstration System** – Prepare specifications and procure equipment for a demonstration system. The contractor would subcontract the work to Fusion UV to build on the experience gained in the pilot testing.
- **Task 6.0, Install and Test** – Install and perform startup testing for demonstration. The customer would conduct the majority of the installation and startup work.
- **Task 7.0, Demonstration** – Operate the demonstration system and collect data for the remainder of the year.
- **Task 8.0, Conduct Commercial Study** – Analyze production data collected from the demonstration program and prepare model plans for commercial applications of the program. Estimate capital and operation and maintenance (O&M) costs for commercial systems and further comparisons to solvent-based ink printing and water-based ink printing.
- **Task 9.0, Seminars and Exhibitions** – Attend and sponsor trade seminars and exhibitions to explain the benefits and viability of the program. Collect and disseminate positive customer feedback on the program. Prepare publications for trade periodicals as appropriate.
- **Task 10.0, Prepare Final Report** – Prepare a written Final Report and review it in accordance with Commission guidelines.

The budget for this program as described in Tasks 1 through 10 above would be around $550,000. The tasks could be accomplished within schedule (Figure 12).

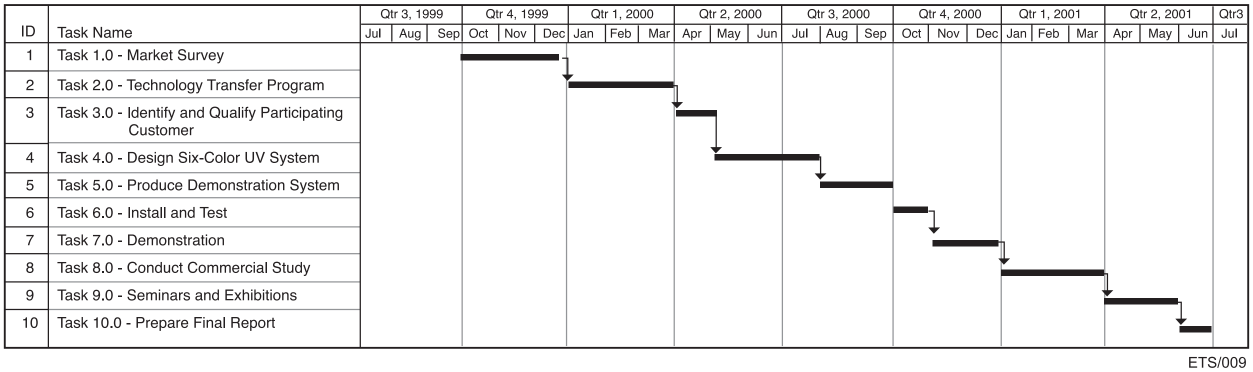

Figure 12. Future Production Test and Demonstration Schedule

Appendix I
An Initial Analysis of UV-Curable Inks for the Plastic Bag Printing Industry

AN INITIAL ANALYSIS OF UV-CURABLE INKS FOR THE PLASTIC BAG PRINTING INDUSTRY

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For:
Southern California Edison Research Division

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I. INTRODUCTION AND BACKGROUND

The Research Division of Southern California Edison contracted with the Institute for Research and Technical Assistance (IRTA) to help them investigate the feasibility and cost of demonstrating Ultraviolet (UV) curable inks for printing on plastic bags. This report provides initial estimates for the UV technology. It compares the cost of using solventborne, waterborne and UV curable inks. It also analyzes the requirements for commercialization of the technology throughout the bag printing industry. Finally, it provides a basic plan for a demonstration in a bag printing facility.

BAG PRINTING PROCESS

There are about 20 bag printers in the jurisdiction of the South Coast Air Quality Management District (SCAQMD) that print on plastic substrates including polyethylene and polypropylene. These bag printers print the bags for tortillas, produce, frozen food or ice, pharmaceutical products and natural fertilizer (manure). The plastic bags are manufactured using a series of extrusion, printing and converting operations. Raw ingredients in the form of beads or pellets are fed into an extruder which produces a continuous film or sheet of polyethylene or polypropylene. In some cases, when the film exits the extruder, it passes through a corona treater which adjusts the surface tension of the film to a predetermined level to prepare the film for printing. The treater also removes wax, slip agents and plasticizers from the surface of the film to enhance ink adhesion. The extruded film is then printed with a flexographic printing press to produce designs and words on the bags. The final process, called converting, forms the printed plastic into bags.

PRINTING REGULATION

SCAQMD Rule 1130 "Graphic Arts," the rule that affects bag printers, was originally adopted on October 3, 1980. It was amended several times between then and September 8, 1995. As part of the 1995 amendments, the SCAQMD staff performed a technology assessment to determine the appropriate controls for the industry. The District concluded that a number of facilities were successfully using waterborne inks and the rule that was ultimately adopted reflected this position. The rule requires flexographic bag printers to use inks with a VOC content of 300 grams per liter or less or to adopt add-on controls. The overall capture and control efficiency of the controls must be at least 67 percent, which would reduce emissions to a level equal to or lower than that which would be achieved through adoption of the 300 gram per liter inks.

For the technology assessment, the District staff visited 18 facilities in their jurisdiction. Some of the firms were using 1,1,1-trichloroethane (TCA) based inks at the time. TCA production has since been banned and the chemical, although it is still available, is very expensive. It is no longer being used in most formulations. Several of the facilities were using waterborne inks and some were also under variance. Since then, a number of facilities have either converted to waterborne inks or purchased a control device. Only two firms remain on variance.

TECHNOLOGY COMPARISON

Some of the firms using waterborne inks do not believe it results in an acceptable product. Associated Poly Bag Corp., the facility that participated in this cost analysis project, is an example of such a company. The plant manager believes the firm has lost business because of the poor quality of the printing with waterborne inks. He is very interested in exploring UV curable inks as an alternative to waterborne inks.

The major barriers for firms in adopting UV curable inks are that the equipment is perceived to be extremely expensive and no bag printer in California has yet adopted the technology. As discussed later, a few bag printing firms in other parts of the country have adopted the technology. Given that it is more beneficial and persuasive to demonstrate the technology in the local area, the SCE Research Division decided to explore the notion of conducting a demonstration in a host bag printing facility in the Basin. The initial cost analysis presented here was performed to assess whether the cost of converting to UV curable inks is reasonable. Based on the findings, SCE's Research Division would decide whether or not to go forward with the demonstration.

STRUCTURE OF DOCUMENT

Section II of this document presents the costs of adopting UV curable inks and compares them to the costs for waterborne inks and solventborne inks with controls. Two scenarios are presented: the cost of purchasing a new system and the cost of retrofitting an existing press. Section III of the document provides information on the experiences of two bag printing firms in other parts of the country that have converted to UV curable inks over the last several years. Section IV of the document presents a discussion of the issues that arise in the commercialization of the technology in Southern California. Finally, Section V scopes out a project that would be used to demonstrate the technology in a Southern California bag printing firm.

II. COST COMPARISON FOR BAG PRINTING OPERATIONS

The cost analysis was performed for Associated Poly Hag Corp. in Anaheim. This facility has two six-color presses and is assumed to be fairly representative of the 20 or so facilities that do bag printing in the South Coast Basin.

Four different scenarios are considered below. In all scenarios, use of solventborne inks is the baseline case. The costs of the baseline are compared with the costs of solventborne inks with controls, waterborne inks and UV curable inks in all cases.

The first scenario assumes that a fixed number of feet of plastic bags—15.6 million feet annually—are printed, regardless of the type of system used. It summarizes the costs of purchasing a new system for the baseline and three alternative cases. The second scenario presents the costs for the same case but for retrofitting an existing press rather than purchasing a new one. This is the scenario most likely to be exercised by firms in the South Coast Basin.

The third and fourth scenarios focus on purchasing a new press and retrofitting an existing press respectively. In these two cases, however, instead of assuming a constant number of feet of bags printed, the line speed was allowed to be fully utilized. The line speed of the press can be much higher with solventborne inks and UV curable inks than with waterborne inks.

The fifth scenario is similar to the third and fourth scenarios in that the line speed of the various technologies was fully utilized. It includes the costs of business gained or lost because of printing quality.

SCENARIO 1: PURCHASE NEW SYSTEM – FIXED NUMBER OF FEET PRINTED

Table 1 presents the capital and operating costs to a typical bag printer for purchasing and operating a new six-color press. The first column shows the costs for the operation assuming solventborne inks are used. The second column shows the costs for adding a thermal oxidizer to the solvent operation. The third column shows the costs for using waterborne inks. The fourth column presents the costs for a system using UV-curable inks. Each of the cost elements is summarized below.

Table 1. Annualized Costs for New System With Standard Production Rate ($)

	Solvent	Solvent With Controls	Water	UV
Capital	163,880	216,025	178,800	178,800
Ink	216,866	216,866	190,740	254,320
Gas	4,887	50,749	17,152	0
Electricity	28,642	57,020	36,336	73,430
Maintenance	20,723	30,083	96,115	14,285
Reject Loss	18,918	18,918	155,520	8,324
Total	453,916	589,661	674,663	529,159

Capital Cost

The capital costs were estimated by Luis Michel of Associated Poly and they are summarized in the table below for each ink type. Installation costs were not included in the figures.

Capital Cost of New Press	
System	**Cost ($)**
Solvent	1,500,000
Solvent With Controls	1,810,000
Water	1,200,000
UV	1,200,000

The capital cost of the press for a solventborne ink operation is estimated at $1.5 million. The cost of a thermal oxidizer is estimated at $300,000 and an enclosure for the press at $10,000; this increases the total capital cost for the system to $1.810 million. The costs of a waterborne system and a UV system are each estimated at $1.2 million.

These capital costs were used to develop the figures of Table 1. To determine the annualized cost for purchasing a new system, the cost of capital was assumed to be 8 percent and the equipment lifetime was fixed at 10 years.

Operating Costs

The operating costs for each type of system are also presented in Table 1 and are explained below.

- **Ink** – The ink usage is based on mileage figures and current annual production. For solventborne inks, the mileage is 1,493 feet printed per pound of ink. For waterborne inks, the mileage is higher, at 2,000 feet printed per pound of ink. This follows from the fact that there is a higher solids content in waterborne inks. For UV curable inks, the mileage is even higher at 4,545 feet printed per pound of ink. UV curable inks are essentially 100 percent solids.

  The cost of solventborne inks is assumed to be $2.80 per pound. The cost of waterborne ink is estimated at $3.30 per pound. The cost of UV curable ink is about $10 per pound.

  As discussed earlier, the costs in Table 1 are all based on an annual printing production of 115.6 million feet per year.

- **Natural Gas** – Gas bills for 3 months in 1996 when Associated Poly was running solventborne inks and 1997 when the firm had converted to waterborne inks were used to estimate the annual cost for gas. The 3 months of use were averaged and multiplied by 12 to obtain an annual usage. The cost of a therm was estimated at 62 cents. In all cases, the press is assumed to operate for the amount of time required to produce 115.6 million feet of bags printed.

  Gas usage is higher for the waterborne inks because of an 800,000 BTU/hr heater that would be required to increase the line speed from 200 feet/min to 300 feet/min. In the case of the solventpress with controls, the gas usage is higher because of the 1.75 MMSTU/hr gas burner on the control device.

- **Electricity** – Electricity usage at Associated Poly was also averaged over 3 months in 1996 and 1997. Again, the monthly average was multiplied by 12 to get an annual usage figure. The annual electrical usage is determined by converting H.P. to kWH by multiplying by 0.75. The firm pays 12 cents per kWH for electricity. Again, in all cases, the press is assumed to operate for the amount of time required to produce 115.6 million feet of bags printed.

  In the case of solventborne inks with controls, the electrical usage is the sum of the annual electrical usage above and the electrical usage from a 75 H.P. blower needed for the control device. In the case of waterborne inks, the press requires two 7.5 H.P. blowers on the heater. In the case of UV curable inks, the total electrical use is much higher, at 180 kW. This includes 140 kW for the lamps and blowers and 40 kW for the chilling system. This is in addition to the electrical requirements for operating the press.

- **Maintenance** – In all cases, it was assumed that the plant ran for three shifts per day, 5 days per week. In die case of solventborne and UV curable inks, maintenance on the machine requires a one shift per week shutdown. In the case of waterborne inks, maintenance on the machine requires a two shift per week shutdown. This is because the waterborne inks, once they cure, harden and are more difficult to clean.

  It was assumed that Associated Poly made 10 color changes per 24-hour day. In the case of solventborne and UV-curable inks, it was assumed that each color change required 5 minutes for a total of 50 minutes per 24-hour day. In the case of the waterborne inks, it was assumed that each color change required 15 minutes for a total of 150 minutes per 24-hour day. Again, the waterborne ink changes take longer because of the properties of the ink.

  Production time is lost because of the cleanup and the color changes. Lost production tine is charged at $150 per hour which is the rate Associated Poly charges customers to print products.

  The solventborne and UV curable ink presses require 8-person hours for maintenance in a 24-hour period. In the case of the solventborne ink with controls, an additional 8-person hours per 24-hour period is required for maintaining the control device. Twenty-four-person hours per 24-hour day are required for maintenance in the case of waterborne inks. The labor rate is assumed to be $6 per hour.

  In the case of waterborne inks, the anilox rollers need to be blasted with abrasive during cleaning. The annual cost is estimated at $28,000.

  In the case of UV curable inks, the lights are replaced every 1,500 hours at a cost of $625 per bulb. On a six color press, there are six lights.

Reject Rate

Associated Poly has a much higher reject rate with waterborne inks than they had with solventborne inks. The reject rate for solventborne inks was about 3 percent whereas it increased to 12 percent with waterborne inks. A 3 percent reject rate would result in a 3 percent lower production. Lost production, as discussed earlier, is charged at $150 per hour. The annual cost of a 3 percent production rate is $38,880; the cost for a 12 percent rate is four times higher, at $155,520.

Customer Loss

Associated Poly estimates that their conversion to waterborne inks resulted in a customer loss of $300,000 annually. This is because the quality of the printed bags is not as good with waterborne inks as with solventborne inks. Because the quality of UV curable inks is even better than solventborne inks, the company estimates that they could increase their customer base by an additional $200,000 annually by converting to UV curable inks. In effect, the firm could charge a premium for the higher quality product. These figures are not included in the analysis except for Scenario 5 below.

SCENARIO 2: RETROFIT EXISTING SYSTEM – FIXED NUMBER OF FEET PRINTED

Table 2 presents the costs for retrofitting an existing press. The assumptions are the same as those for the new system case in Table 1 except for the capital cost which is based on required press modifications. In the case of solvent, no modifications of the press were required. In the case of solvent with a control device, the capital cost of the control device and enclosure was estimated at $310,000 by a vendor. In the case of waterborne inks, the firm needs six doctor blades ($10,000 per blade), a corona heater ($30,000) and an unproved heater ($35,000). In the case of the UV curable inks, the retrofit cost of $217,935 was based on a quotation from a vendor. Again, the capital cost was amortized over a 10-year period and the cost of capital was 8 percent.

Table 2. Annualized Costs for Retrofit System With Standard Production Rate ($)

	Solvent	Solvent With Controls	Water	UV
Capital	0	55,125	18,625	35,905
Ink	216,866	216,866	190,740	254,320
Gas	4,887	50,749	17,152	0
Electricity	28,642	57,020	36,336	73,430
Maintenance	20,723	30,083	96,115	14,285
Reject Loss	18,918	18,918	155,520	8,324
Total	290,036	428,761	514,488	386,264

SCENARIO 3: NEW SYSTEM – LINE SPEED FULLY UTILIZED

For the cost figures in Tables 1 and 2, it was assumed that the company would produce a constant number of feet of printed bags. Under this assumption, the presses running solventborne and UV curable inks would not operate for part of the year. This follows from the fact that the tine speed of the presses using solventborne and UV curable ink is higher than the line speed of the press using waterborne inks. In fact, because the line speed is higher than for waterborne ink presses, the same amount of printing can be done in a shorter period of time. The company can take advantage of this in two ways. First, the firm can shorten the work day by eliminating a shift for much of the year. This would reduce total plant labor costs substantially. Second, the company can use the increased line speed to increase production by obtaining additional customers. These savings are not quantified in Tables 1 and 2 where the values are based on a constant number of bag feet printed.

This scenario assumes that the number of bags printed is limited only by the line speed of the particular technology. In other words, printing takes place for three shifts each day for the entire year and the line speed of each technology is fully utilized. The table below compares the number of bag feet that can be printed in a year for each of the technologies.

Number of Bag Feet Printed Annually	
System	**Number of Bags**
Solvent	164.3
Solvent With Controls	164.3
Water	115.6
UV	375.5

Table 3 compares the cost figures for this scenario assuming the firm purchases a new system. The values for the entry called "increased production" reflect the fact that the line speed of the solventborne and UV-curable ink is faster than that of waterborne ink. The faster line speed means a higher production capacity. The value used for increased production is based on a production cost of $150 per hour. Associated Poly uses this figure currently for charging customers.

Table 3. Annualized Costs for New System With Line Speed Fully Utilized ($)

	Solvent	Solvent With Controls	Water	UV
Capital	163,880	216,025	178,800	178,800
Ink	289,154	289,154	190,740	254,320
Gas	6,516	-71,051	17,152	0
Electricity	38,189	57,020	36,336	73,430
Maintenance	27,630	40,110	96,115	14,285
Reject Loss	38,880	38,880	155,520	38,880
Increased Prod	(210,210)	(210,210)	0	(560,563)
Total	354,039	502,030	674,663	613,030

SCENARIO 4: RETROFIT – LINE SPEED FULLY UTILIZED

Table 4 compares the costs of the various systems for the case where a firm retrofits an existing press rather than purchasing a new one. Again, as was the case for Table 3, it was assumed that the line speed would be fully utilized for each technology.

Table 4. Annualized Costs for Retrofit System With Line Speed Fully Utilized ($)

	Solvent	Solvent With Controls	Water	UV
Capital	0	55,125	18,625	35,905
Ink	289,154	289,154	190,740	762,960
Gas	6,516	-71,051	17,152	0

Electricity	38,189	57,020	36,336	149,723
Maintenance	27,630	40,110	96,115	43,230
Reject Loss	38,880	38,880	155,520	38,880
Increased Prod	(210,210)	(210,210)	0	(560,563)
Total	190,159	341,130	514,488	470,135

SCENARIO 5: NEW AND RETROFIT CASES INCLUDING CUSTOMER LOSS OR GAIN

Table 5 summarizes the total costs of each scenario (new system with standard production rate, retrofit system with standard production rate, new system with line speed fully utilized and retrofit system with line speed fully utilized) including a customer loss factor. As mentioned earlier, Luis Michel of Associated Poly estimated that the business lost from the conversion to waterborne inks amounted to $300,000 per year. The business increase through adoption of UV curable inks was estimated at $200,000. In Table 5, the total cost figures from Tables 1 through 4 were adjusted. The annualized cost of waterborne inks was increased by $300,000 and the cost of UV curable inks was decreased by $200,000.

Table 5. Annualized Cost Scenarios Including Customer Loss Factor ($)

	Solvent	Solvent With Controls	Water	UV
New, Standard Production Rate	453,916	589,661	974,663	329,159
Retrofit, Standard Production Rate	290,036	428,761	814,488	186,264
New, Line Speed Fully Utilized	354,039	502,030	974,663	413,030
Retrofit, Line Speed Fully Utilized	190,159	341,130	814,488	270,135

DISCUSSION OF RESULTS

New and Retrofit Cases – Fixed Number of Feet Printed

The values of Table 1 demonstrate that solventborne ink with no controls is the lowest cost method. This method, however, cannot be used in the Basin or in other parts of the country with similar regulations. SCAQMD Rule 1130 does not allow the use of solventborne inks without controls. Bag printers with flexographic presses can use inks with no more than 300 grams of VOC per liter or they can use a control device with overall capture and control efficiency of 67 percent. Some of the firms in the Basin have installed control devices and some have converted to waterborne inks to comply with the rule requirements.

The lowest cost option in Table 1 that complies with Rule 1130 is the use of UV curable inks. That option is about $60,000 per year less costly than using solventborne inks with controls. The major reason that the UV system is less costly than the solvent system with controls is that, aside from the ink and electrical costs, all other operating costs are lower. The UV system is also about $145,000 less costly than converting to waterborne inks. Although the capital cost of the waterborne ink system is the same as for the UV system, the maintenance and reject loss costs are much higher. The same general trends apply for the figures of Table 2 which summarizes the retrofit case.

New and Retrofit Cases – Line Speed Adjustment

The values of Table 3 and 4 provide a very interesting picture. In both cases, the solventborne system with controls is a lower cost option than the UV system. This follows from the fact that the line speed of the UV system is higher than the line speed of the solvent system. The UV system operates for many more hours in the year and the operating costs are higher as a result. Although the increased production brings in additional sales, this is not enough to offset the higher operating costs. In particular, the cost of the ink is more than three times greater than the ink cost in Tables 1 and 2 and this is the major reason that the UV system is more costly than the solvent system with controls. The expense of the UV inks is an issue mentioned by one of the firms that has recently installed a UV system for printing on plastic substrates (see next section).

Cases Including Customer Loss/Gain

When the customer loss factor is considered, the lowest cost option is solventborne inks without controls. Firms in the Basin cannot exercise this option, however. The next lowest cost option is UV curable inks in all four scenarios. The use of waterborne inks is a very costly option when customer loss is taken into account.

Electricity Costs

In all four scenarios presented in Tables 1 through 4, the electricity cost for the UV system is higher than for any of the other systems. It is higher by about 30 percent than the solvent system with controls and is more than double the electricity cost for the waterborne system.

II. FIRMS USING UV CURABLE INKS

Two primers in the United States are currently using UV curable inks for flexographic printing on polyethylene or polypropylene substrates. Maine Poly Inc. in Maine and Trinity Packaging in Virginia have both installed six color wide web flexographic printing lines over the last 5 years. Information about Maine Poly's experience was gathered from published articles from "Flexo" in the October and December, 1995 issues.

Both facilities have successfully implemented UV printing systems and they are interested in promoting the technology in hopes that the ink cost will decline with larger demand for the product. As discussed earlier, the UV ink cost is very high. Trinity Packaging has a separate walled-off room which houses the UV printing press. They extend an open invitation to anyone interested in viewing the technology in a workplace setting.

MAINE POLY INC.

Maine Poly retrofitted their six-color 33-inch press in 1994 which was very early on in the UV development process. Initially the company had difficulty with heat retention and surface tension on extensible films. The high energy output of the UV lamps—typically between 400 and 600 watts per linear inch—creates a large amount of heat on the printing drum. The drum expands from the heat which causes the print and process dot size to swell. This problem was addressed by including a chiller unit which keeps the drum from expanding excessively. In fact, this feature is now routinely included in estimates provided by UV light manufacturers for retrofitting lines.

Another issue was surface tension on extensible films like polyethylene and polypropylene. The UV inks do not adhere well to the printing surface without additional treatment. This phenomenon also occurs with waterborne inks. To overcome the problem, a corona treater was installed to improve the adhesion. This feature, like the chiller for the drum, is now commonly quoted by the UV light manufactures as part of the retrofit package.

TRINITY PACKAGING

IRTA staff discussed this firm's decision to purchase a new press with David Williams of Trinity Packaging. The firm had no experience in printing with solventborne inks in flexographic bag printing before they decided to purchase a new UV press. The new six-color 62 inch flexographic press was purchased in 1996 with the hope that the firm could capture a new market. Because of regulatory requirements in the area, Trinity Packaging would have had to install a control device if they had opted for a press using solventborne inks.

Trinity Packaging believes that the superior printing quality achievable by UV curable inks makes the company competitive with companies using traditional printing methods. Print samples and line speeds demonstrate the quality and speed that UV offers. Trinity Packaging staff are convinced that their choice of new UV press allowed the firm to avoid costly mistakes and necessary modifications that sometimes attend retrofits. In fact, they are uncomfortable recommending the retrofit option to other printers. They strongly suggest that printers purchase a new press instead.

Trinity Packaging indicates that the one drawback to using the UV system is the cost of the ink. They agree with the $10 per pound of ink estimate used in this analysis. It is their hope that as more firms adopt the UV process, the ink price will decline. Even with the higher ink costs, however, they can maintain profitability, because of the higher line speed and the premium they receive for the higher quality printing they can provide.

IV. COMMERCIALIZATION

There are at least 20 dedicated bag printers in the South Coast Basin that use flexographic presses for printing on polyethylene and/or polypropylene. IRTA estimates that these printers operate more than 50 presses. Approximately one-third of these presses are four color, one-half are six color and the remainder print a range of colors from two to 10.

The SCAQMD technology assessment involved visits to 18 printers in the SCAQMD jurisdiction and visits to two additional printers that were probably located in the Ventura area. At this stage, 14 of the 20 printers are using waterborne inks, two printers are still on variance and four printers have installed control devices.

Two of the printers using waterborne inks are extremely dissatisfied with the quality of the printing. Both indicate that they have lost customers because of the conversion. They believe that virtually all of the printers using waterborne inks feel the same way.

In this light, at least 18 printers in the SCE territory are using a very limited technology currently. They would be candidates for conversion to the UV system, either through retrofitting existing presses or purchasing new UV presses. These firms are likely to be using at least 45 presses. As discussed below, the plan for a demonstration of the UV technology could be very persuasive in convincing some of these firms to convert to UV curable inks.

In addition to the bag primers in the Basin, the SCAQMD) estimates that there are an additional 200 or so flexographic printers. Although these firms do not print on plastic, their processes are also candidates for conversion. All flexographic printers in the SCAQMD jurisdiction face the same regulations as the bag printers. In other words, they must use waterborne inks or use a control device. There maybe many other flexographic printers that could benefit from the information generated in a demonstration of the UV technology.

V. DEMONSTRATION PARAMETERS

SCE is considering funding a demonstration of the UV technology in a bag printing facility in Southern California. The purpose of a test and demonstration of the UV technology would be to show bag and other flexographic printers the technical feasibility of the process and to do a more complete analysis of the costs and advantages and disadvantages of the emerging technology. Firms are always more interested in a technology adopted by another firm that has virtually the same process as theirs.

This section presents a preliminary list of tasks and describes the effort that would be necessary to perform the demonstration.

TASK 1: SELECT DEMONSTRATION SITE

Under this task, an appropriate demonstration site would be selected and IRTA staff would assist in this endeavor. Associated Poly has volunteered to serve as the demonstration site. The firm is very interested in converting to UV if the technical feasibility is verified. The firm also has two six-color presses which is the most common type of press used in the Basin. One of these, in particular, is especially suited for a retrofit to UV. SCE may not be able to use Associated Poly as the demonstration site because the firm is located in Anaheim which is not in Edison's service territory. Westbag has also offered a press for retrofitting. This press, however, is a four-color press, a type of press less common than the six-color press. It may be necessary to examine other options for sites.

TASK 2: CONTRACT WITH DEMONSTRATION SITE AND VENDOR

IRTA has identified a vendor, Fusion, that is very interested in collaborating on the demonstration. They are members of RadTech, a trade organization that fosters the increased use of UV technologies and they are very active in developing new applications. Fusion has indicated that they would be willing to share in the cost of the demonstration. IRTA has offered to help publicize the results of the project and to assist in disseminating the findings to make this cooperation more attractive.

The user site selected for the demonstration should be one that would be willing to convert to the UV system if the results of the demonstration were favorable. Under this circumstance, the host firm would also share in the cost of the demonstration if they agreed to pay part of the retrofit or press purchase cost.

SCE would have to negotiate contracts with the host site and the vendor.

TASK 3: ENGINEERING DESIGN/INSTALLATION/STARTUP OF SYSTEM

This task would involve assessing the demonstration site and determining the best approach to a demonstration. It is likely, because of cost limitations, that the best approach would be to retrofit an existing press rather then purchasing a new one. Fusion would determine the steps needed for retrofit and the cost which would depend on the make and type of press selected for retrofit. Fusion, the host site and IRTA would assist in the design, installation and startup of the system.

TASK 4: OPERATION OF SYSTEM

Operating the system for a period of time will provide useful data for the technical feasibility and cost analysis. It will also allow other bag printers and owners of flexographic printers in the Basin to see the system in operation and talk to the host facility owner, Fusion, IRTA and Edison staff about its features and performance (see Task 5 below). If Edison must complete the project by the end of 1997, the operation phase would be short—probably no more than 2 months. If the project starts in 1997 and is allowed to continue in 1998, then the operation phase should be longer—of the order of 6 months. This will allow enough time to collect data for analysis and for other printers to visit the host site.

TASK 5: INTERACT WITH OTHER BAG PRINTERS AND FLEXOGRAPHIC PRINTERS

This task would involve disseminating information on the demonstration to other bag and flexographic printers in the Basin, IRTA staff could visit one of the trade association meetings to describe the project and invite firms to inspect the host site. IRTA could also arrange a mail-out for the other flexographic printers in the area. This would ensure a widespread interest and response for visiting the host site.

TASK 6: PERFORM TECHNICAL FEASIBILITY AND COST ANALYSIS

Under this task, IRTA would analyze the performance and cost of the UV system. The cost comparison in this document would serve as an initial basis for collecting and analyzing the costs of the actual system in operation.

TASK 7: PERFORM FDA ANALYSIS

Under this task, IRTA would investigate the FDA requirements that apply to UV curable inks. This task could involve functional barrier testing which would be conducted in conjunction with Fusion and perhaps RadTech.

TASK 8: WRITE AND DISTRIBUTE FINAL REPORT

IRTA staff would prepare a draft and final report on the results of the project. This report would be made available to the bag and other flexographic printers in the Basin. If Edison agreed, Cal-EPA's Department of Toxic Substances Control (DTSC) would be willing to publish and disseminate the final report at no cost. DTSC is a member of IRTA's Pollution Prevention Center and publishes reports and case studies developed during projects.

TASK 9: ARRANGE AND HOLD CONFRENCE FOR INDUSTRY AT CTAC

In conjunction with RadTech and the SCAQMD, IRTA would arrange a conference at CTAC to disseminate the results of the study to bag and flexographic printers in the Basin. Speakers would include representatives from the Edison, the host site, Fusion, SCAQMD and IRTA. During the operation phase, the retrofitted printing press could be filmed in operation and this film could be shown during this conference.

TASK 10: DEMONSTRATE FEASIBILITY AND COST OF UV/OZONE CONTROL SYSTEM

Most of the firms that have adopted controls to comply with SCAQMD Rule 1130 have purchased thermal oxidizers. In general, these devices use a great deal of gas. IRTA has a small variable cfm UV/ozone control device permitted by SCAQMD for use in demonstrations in new applications. This device could be demonstrated in a bag printing facility as part of this project if Edison was interested. If this task were performed, then the feasibility and cost could be included in the final report and in the information provided to printers during the CTAC conference.

Appendix II
Cost Comparison for Bag Printing Operations

COST COMPARISON FOR BAG PRINTING OPERATIONS

The cost analysis was performed for Associated Poly Bag Corp. in Anaheim. This facility has two six-color presses and is assumed to be fairly representative of the 20 or so facilities that do bag printing in the South Coast Basin.

PURCHASE NEW SYSTEM

Table I presents the capital and operating costs to a typical bag printer for purchasing and operating a new six-color press. The first column shows the costs for the operation assuming solventborne inks are used. The second column shows the costs for adding a thermal oxidizer to the solvent operation. The third column shows the costs for using waterborne inks. The fourth column presents the costs for a UV system using UV-curable inks. Each of the cost elements is summarized below.

Capital Cost

The capital costs for purchasing a press, whether it be one to use solventborne, waterborne or UV curable inks, are similar. These costs are summarized in the table below. In all instances for the new press, no installation costs were included. The costs were estimated by Luis Michel of Associated Poly.

Capital Cost of Systems

System	Press Cost ($)
Solvent	1,500,000
Solvent With Controls	1,810,000
Water	1,200,000
UV	1,200,000

The capital cost of the press for a solventborne ink operation is estimated at $1.5 million. The cost of a thermal oxidizer is estimated at $300,000 and an enclosure for the press at $10,000; it increases the total capital cost for the system to $1.810 million. The cost of a waterborne system is estimated at about $1.2 million. The cost of a UV system is also estimated at $1.2 million.

These capital and installation costs are amortized at 8 percent over 10 years and presented in Table 1.

Operating Costs

The operating costs for each type of system are also presented in Table 1 and are explained below.

Ink. The ink usage is based on mileage figures and current annual production. For waterborne inks, mileage is calculated to be 2,000 feet printed per pound of ink. For solventborne inks, the mileage is lower, at 1,493 feet printed per pound of ink. This follows from the fact that there are higher solids in waterborne inks. For UV curable inks, it is much higher, at 4,545 feet printed per pound of ink. UV curable inks are essentially 100 percent solids.

The cost of solventborne inks is assumed to be \$2.80 per pound. The cost of waterborne ink is estimated at \$3.30 per pound. The cost of UV curable ink is about \$10 per pound.

The costs in Table 1 are all based on an annual printing production of 115.6 million feet per year. As discussed later, the faster linespeeds of the UV curable and the solventborne ink presses have strong implications for the cost analysis.

<u>Natural Gas</u>. Gas bills for 3 months in 1996 when Associated Poly was running solventborne inks and 1997 when the firm had converted to waterborne inks were used to estimate the annual cost for gas. The 3 month of use were averaged and multiplied by 12 to obtain an annual usage. The cost of a therm was estimated at 62 cents. In all cases, the press is assumed to operate for the amount of time required to produce 115.6 million feet of bags printed.

Gas usage is higher for the waterborne inks because of an 800,000 BTU/hr heater that was installed to increase the line speed from 200 feet/mm to 300 feet/mm. In the case of the solvent press with controls, the gas usage is higher because of the 1.75 MMBTU/hr gas burner on the control device.

<u>Electricity</u>. Electricity usage at Associated Poly was also averaged over 3 months in 1996 and 1997. Again, the monthly average was multiplied by 12 to get an annual usage figure. The annual electrical usage is determined by converting H.P. to kWH by multiplying by 0.75. In all cases, the press is assumed to operate for the amount of time required to produce 115.6 million feet of bags printed.

In the case of solventborne inks with controls, the electrical usage is the sum of the annual electrical usage above and from a 75 H.P. blower on the control device. In the case of waterborne inks, the press requires two 7.5 H.P. blowers on the heater. In the case of UV curable inks, the total electrical use is much higher, at 180 kW. This consists of 140 kW from the lamps and blowers and 40 kW from the chilling system. This is in addition to the electrical requirements for operating the press.

<u>Maintenance</u>. In all cases, it was assumed that the plant ran for three shifts per day, 5 days per week. In the case or solventborne and UV curable inks, maintenance on the machine requires a one shift per week shutdown. In the case of waterborne inks, maintenance on the machine requires a two shift per week shutdown. This is because the waterborne inks, once they cure, harden and are more difficult to clean.

It was assumed that Associated Poly made 10 color changes per day. In the case of solventborne and UV curable inks, it was assumed that each color change required 5 minutes for a total of 50 minutes per day. In the case of the waterborne inks, it was assumed that each color change required 15 minutes for a total of 150 minutes per day. Again, the ink changes take longer because of the properties of the ink.

Production time is lost because of the cleanup and the color changes. Lost production time is charged at \$150 per hour which is the rate Associated Poly charges customers to print products.

The solventborne and UV curable ink presses require 8-person hours for maintenance in a 24-hour period. In the case of the solventborne ink with controls, an additional 8-person hours per 24-hour period is required for maintaining the control device. Twenty-four-person hours per 24-hour day are required for maintenance in the case of waterborne inks. The labor rate is assumed to be $6 per hour.

In the case of waterborne inks, the anilox rollers need to be blasted with abrasive during cleaning. The annual cost is estimated at $28,000.

In the case of UV curable inks, the lights are replaced every 1,500 hours at a cost of $625 per bulb. On a six color press, there are six lights.

<u>Reject Rate</u>

Associated Poly has a much higher reject rate with waterborne inks than they had with solventborne inks. The reject rate for solventborne inks was about 3 percent whereas it increased to 12 percent with waterborne. A 3 percent reject rate would result in a 3 percent lower production. Lost production, as discussed earlier, is charged at $150 per hour. The annual cost of a 3 percent production rate is 38,880; the cost for a 12 percent rate is four times higher, at $155,520.

<u>Customer Loss</u>

Associated Poly estimates that their conversion to waterborne inks resulted in a customer loss of $300,000 annually. This is because the quality of the printed bags is not as good with waterborne inks as with solventborne inks. Because the quality of UV curable inks is even better than solventborne inks, the company estimates that they could increase their customer base by an additional $200,000 annually. These figures have not been used in this analysis.

<u>Line Speed Implications</u>

For the cost figures in Table 1, it was assumed that the company would produce a uniform number of feet of printed bags. In fact, because the linespeed of the solventborne and UV curable ink presses is much higher than for waterborne ink presses, the same amount of printing can be done in a shorter amount of time. The company can take advantage of this in two ways. First, the firm can shorten the work day by eliminating a shift for much of the year. This would reduce total plant labor costs substantially. Second, the company can use the increased line speed to increase production by obtaining additional customers. Thus with solventborne and UV curable inks, these savings are not quantified in Table 1.

<u>RETROFIT EXISTING SYSTEM</u>

The assumptions made under the new system case above are all the same except for the capital cost which is based on the required modifications. In the case of solvent, no modifications of the press were required. In the case of solvent with a control device, the capital cost of $300,000 was based on a quotation from a vendor. In the case of waterborne inks, the firm needs six doctor blades ($10,000 per blade), a corona treater ($30,000) and an improved heater ($35,000). In the case of the UV curable inks, the retrofit costs of $217,935 was based on a quotation from a vendor. Again, the capital cost was amortized over a 10-year period and the interest rate was 8 percent.

DISCUSSION OF RESULTS

The values of Table 1 demonstrate that solventborne ink with no controls is the lowest cost method. This method, however, cannot be used in the Basin. In the South Coast Basin, the South Coast Air Quality Management District (SCAQMD) does not allow the use of solventborne inks without controls. In Rule 1130, bag printers with flexographic presses can use inks with no more than 300 grams of VOC per liter or they can use a control device with overall capture and control efficiency of 67 percent. Some of the firms in the Basin have installed control devices and some have converted to waterborne inks.

The lowest cost option that complies with Rule 1130 is the use of UV curable inks. That option is less about $60,000 per year less costly than using solventborne inks with controls. The major reason that the UV system is less costly than the solvent system with controls is that, aside from the ink and electrical costs, all other operating costs are lower. The UV system is also about $145,000 less costly than converting to waterborne inks. Although the capital cost of the waterborne ink system is the same as for the UV system, the maintenance and reject loss costs are much higher. The same general trends apply for the retrofit case.

The electricity cost for the UV system is higher than for any of the other systems. They are higher by about 30 percent than the solvent system with controls and they are more than double the electricity cost for the waterborne system.

TABLE 1
ANNUALIZED COSTS FOR NEW SYSTEM WITH STANDARD PRODUCTION RATE ($)

	Solvent	Solvent With Controls	Water	UV
Capital	163,880	216,025	178,800	178,800
Ink	216,866	216,866	190,740	254,320
Gas	4,887	50,749	17,152	0
Electricity	28,642	57,020	36,336	73,430
Maintenance	20,723	30,083	96,115	14,285
Reject Loss	18,918	18,918	155,520	8,324
Total	453,916	589,661	674,663	529,159

TABLE 2
ANNUALIZED COSTS FOR RETROFIT SYSTEM WITH STANDARD PRODUCTION RATE ($)

	Solvent	Solvent With Controls	Water	UV
Capital	0	55,125	18,625	35,905
Ink	216,866	216,866	190,740	254,320
Gas	4,887	50,749	17,152	0
Electricity	28,642	57,020	36,336	73,430
Maintenance	20,723	30,083	96,115	14,285
Reject Loss	18,918	18,918	155,520	8,324
Total	290,036	428,761	514,488	386,264

Appendix III
One-Color Pilot Test Results

Institute for Research and Technical Assistance
a nonprofit organization

IRTA

MEMO

Date: July 15, 1998

To: List

From: Mike Morris, Katy Wolf, IRTA

Subject: Cost Analysis For UV System

I am enclosing a cost analysis of the UV system based on the one-lamp tests at Associated Poly Bag Corp. over the last several months. We are scheduled to have a meeting on July 22 at Associated Poly at 9:00 AM. David Snyder of Fusion will join the meeting by phone.

The purpose of the meeting is to discuss the cost analysis that we have performed and to get input from all parties—Edison, Associated Poly and Fusion—one whether the assumptions we used are the right ones or whether we should use other assumptions and analyze other scenarios.

The enclosed cost analysis includes several cases. For all cases, the total costs are summarized at the top of the sheet. The detailed breakdown of the costs is given below the summary of the total costs. The assumptions for all cases are the first sheet entitled "Assumptions."

The first case, entitled "Cambro Job," is the analysis for one job that used white ink only. Solvent is treated as the baseline and that is why the capital cost for the solvent system is listed as zero.

The second case is the analysis for fixed production over a year; note that the feet of film processed is the same for water, UV, solvent and solvent with controls.

The third case is the analysis for full production over a year. In this case the feet processed varies depending on the technology. More feet can be processed in the case of UV because the press speed can be greater.

The fourth case is the analysis for fixed production over a year for any bag printer located in the South Coast Basin that currently uses waterborne ink. In this case, the capital cost for a water system is set at zero because the investment has already been made.

The fifth and final case is the analysis for fixed production over a year for Associated Poly in particular. This scenario assumes that the capital investment for the UV system will include only the purchase of a chiller by Associated Poly.

All of the assumptions and cases will be discussed at the meeting. If you have questions, feel free to call Mike or me at (310) 453-0450.

List:
- Water Neeld
- Mazen Sadeq
- Pradeep Sharma
- Russ Krinker
- Rick Varagnat
- David Synder

2800 Olympic Blvd., Suite 101
Santa Monica, CA 90404
(310) 453-0450 Fax (310) 453-2660

Assumptions

Feet Processed – Original job used INX inks and 130,000 feet were processed. Second, and better, run was with Sun Chemical inks and 100,000 were processed. The 100,000 feet processed was used as the benchmark for the other technologies. For fixed production scenarios, Associated Poly's estimate of 115 million feet produced annually was used. For full production scenarios, feet processed was calculated by multiplying run time by line speed.

Line Speed – Line speed was measured for the UV ink runs. Line speed for the other technologies were based on operator estimates.

Run Time – Time to complete a fixed production amount based on line speed. Distance/Velocity = Time. Full production scenarios used annual operating hours for run time.

Maintenance Time – Time to conduct maintenance after job is complete. In the case of UV, the maintenance time is considered to be the time of the run. As per conversations with Jessie, an extra person would have to be working full time to keep up with cleaning duties. Set-up time is not included.

Maintenance/Labor Cost – Worker compensation is approximately $9 per hour. Two workers are needed to conduct maintenance and operate the press. In the case of UV, a third person would be conducted maintenance full time.

Ink Usage – Ink usage was measured for the UV inks. Water-borne ink usage was based on operator estimates. Solvent-borne ink usage was calculated by comparing solids content between water-borne and solvent-borne inks. Consistency questions remain for dry weights of colored UV inks.

Ink Cost per Pound – Based on actual costs of Sun Chemical UV water-borne and UV inks. Price per pounds is calculated by weighted average of white inks (50%) and all other inks (50%).

Ink Cost – Ink cost per pounds multiplied by the ink usage.

Reject Loss – Loss of completed product due to poor quality, etc. based on L. Michel comments on estimated rejection rate of 10% for water, 3% for solvent, and 2% for UV. Dollar lost is calculated by multiplying reject rate by the run item and by the $150/hr rate that Associated Poly charges.

Gas Cost – Natural gas costs for usage of additional heater (water) or for afterburner (solvent w/control device). Therm cost is $0.62. Heater BTU/hr is 800,000. Afterburner BTU/hr is 1,750,000.

Electrical Cost – Base electrical usage is calculated by averaging previous electric bills in 1996 (solvent) and 1997 (water). Hourly usage is calculated by divided by annual operating hours. Additional electrical costs are included for two 7.5 HP blowers (water), a 75 HP blower (solvent w/control) and 41 kWH for the light and chiller. The firm pays 12 cents per kWH of electricity.

Capital Costs – No capital costs are included for the water or solvent scenarios. For solvent with controls and UV, the annualized costs were divided by annual operating hours and then multiplied by run time.

Cambro Job

CAMBRO Job

	Water	UV	Solv	Solv w/Cntrl
Ink	52.14	96.25	59.08	59.08
Gas	23.81	0.00	0 00	27.99
Electricity	18.29	16.24	10.33	38.68
Maint/Labor	95.40	59.40	84.60	84.60
Reject Loss	72.00	6.60	18.90	18.90
Capital	14.33	12.66	0.00	37.10
Total	275.95	191.14	172.91	266.36

Ink Cost

	Water	UV	Solv	Solv w/Cntrl
Ink Used	15.8	11	21.1	21.1
Ink Cost/lb	3.3	8.75	2.8	2.8
Ink Cost	**52.14**	**96.25**	**59.08**	**59.08**

Maint/Labor Cost

	Water	UV	Solv	Solv w/Cntrl
Feet Processed	100,000	100,000	100,000	100,000
Speed	350	750	400	400
Run Time	4.8	2.2	4.2	4.2
Maint Time	0.5	2.2	0.5	0.5
Hours Charged	10.6	6.6	9.4	9.4
Labor Rate	9	9	9	9
Maint/Labor Cost	**95.40**	**59.40**	**84.60**	**84.60**

Electrical Costs

	Water	UV	Solv	Solv w/Cntrl
Added kWH	11.25	41	0	56.25
kWH Cost	0.12	0.12	0.12	0.12
Added Cost Elect/Hr	1.35	4.92	0	6.75
Base Electrical/Hr	2.46	2.46	2.46	2.46
Run Time	4.8	2.2	4.2	4.2
Elect Cost	**18.29**	**16.24**	**10.33**	**38.58**

Gas Costs

	Water	UV	Solv	Solv w/Cntrl
Added Therms	8	0	0	10.75
Therm Cost	0.62	0.62	0.62	0.62
Added Cost Therm/Hr	4.96	0	0	6.665
Base Therm/Hr	0	0	0	0
Run Time	4.8	2.2	4.2	4.2
Gas Cost	23.81	0.00	0.00	27.99

Cambro Job

Reject Loss

	Water	**UV**	**Solv**	**Solv w/Cntrl**
Charge Rate/Hr	150	150	150	150
Run Time	4.8	2.2	4.2	4.2
Reject Rate	10%	2%	3%	3%
Reject Loss	**72.00**	**6.60**	**18.90**	**18.90**

Capital Cost

	Water	UV	Solv	Solv w/Cntrl
Total Capital Cost	115,000	220,000	0	338,000
Annualized Capital Cost	18,625	35,905	0	55,125
Hourly Capital Cost	2.98	5.75	0.00	8.83
Run Time	4.8	2.2	4.2	4.2
Capital Cost	14.33	12.66	0.00	37.10

Annualized Costs **Fixed Production**

Retrofit System

	Water	UV	Solv	Solv w/Cntrl
Ink	322324	390219	366348	366348
Gas	27304	0	0	32103
Electricity	20973	18958	11849	44362
Maint/Labor	149550	73105	98868	98868
Reject Loss	82571	7707	21675	21675
Capital	18625	35905	0	55125
Total	**621547**	**525894**	**498740**	**618481**
Income ($150/Hr)	**825750**	**825750**	**825750**	**825750**
Net Income	**204203**	**299856**	**327010**	**207269**

Ink Cost

	Water	UV	Solv	Solv w/Cntrl
Ink Used	57800	33524	77452	77452
Ink Cost/Lb	5.58	11.64	4.73	4.73
Ink Cost	**322524**	**390219**	**366348**	**366348**

Maint/Labor Cost

	Water	UV	Solv	Solv w/Cntrl
Feet Processed	115,600,000	115,600,000	115,600,000	115,600,000
Speed	350	750	400	400
Run Time	5505	2569	4817	4817
Maint Time	1248	2985	676	676
Hours Charged	13506	8123	10985	10985
Labor Rate	9	9	9	9
Misc Cost	28000	6422	0	0
Maint/Labor Cost	**149550**	**73105**	**98868**	**98868**

Electrical Costs

	Water	UV	Solv	Solv w/Cntrl
Added kWH	11.25	41	0	56.25
kWH Cost	0.12	0.12	0.12	0.12
Added Cost Elect/Hr	1.35	4.92	0	6.75
Base Electrical/Hr	2.46	2.46	2.46	2.46
Run Time	5505	2569	4817	4817
Elect Cost	**20973**	**18958**	**11849**	**44362**

Gas Costs

	Water	UV	Solv	Solv w/Cntrl
Added Therms	8	0	0	10.75
Therm Cost	0.62	0.62	0.62	0.62
Added Cost Therm/Hr	4.96	0	0	6.665
Base Therm/Hr	0	0	0	0
Run Time	5505	2569	4817	4817
Gas Cost	**27304**	**0**	**0**	**32103**

Reject Loss

	Water	UV	Solv	Solv w/Cntrl
Charge Rate/Hr	150	150	150	150
Run Time	5505	2569	4817	4817
Reject Rate	10%	2%	3%	3%
Reject Loss	**82571**	**7707**	**21675**	**21675**

Capital Cost

	Water	UV	Solv	Solv w/Cntrl
Total Capital Cost	115,000	220,000	0	338,000
Annualized Capital Cost	18625	35905	0	55125

Annualized Costs **Full Production**
Retrofit System

	Water	UV	Solv	Solv w/Cntrl
Ink	322538	838232	416618	416618
Gas	27305	0	0	36691
Electricity	20974	40627	13542	50701
Maint/Labor	144892	152379	109404	109404
Reject Loss	82575	16515	24773	24773
Capital	18625	35905	0	55125
Total	**616909**	**1083658**	**564337**	**693312**
Income	**825750**	**1769464**	**943714**	**943714**
Net Income	**208841**	**685806**	**379377**	**250403**

Ink Cost

	Water	UV	Solv	Solv w/Cntrl
Feet Processed	115,605,000	247,725,000	132,120,000	132,120,000
Mileage (feet per lb)	2000	3440	1500	1500
Ink Used	57803	72013	88080	88080
Ink Cost/Lb	5.58	11.64	4.73	4.72
Ink Cost	**322538**	**838232**	**416618**	**416618**

Maint/Labor Cost

	Water	UV	Solv	Solv w/Cntrl
Feet Processed	115,605,000	247,725,000	132,120,000	132,120,000
Speed	350	750	400	400
Run Time	5505	5505	5505	5505
Maint Time	989	5921	573	573
Hours Charged	12988	16931	12156	12156
Labor Rate	9	9	9	9
Misc Cost	28000	6422	0	0
Maint/Labor Cost	**144892**	**152379**	**109404**	**109404**

Electrical Costs

	Water	UV	Solv	Solv w/Cntrl
Added kWH	11.25	41	0	56.25
kWH Cost	0.12	0.12	0.12	0.12
Added Cost Elect/Hr	1.35	4.92	0	6.75
Base Electrical/Hr	2.46	2.46	2.46	2.46
Run Time	5505	5505	5505	5505
Elect Cost	**20974**	**40627**	**13542**	**50701**

Gas Costs

	Water	UV	Solv	Solv w/Cntrl
Added Therms	8	0	0	10.75
Therm Cost	0.62	0.62	0.62	0.62
Added Cost Therm/Hr	4.96	0	0	6.665
Base Therm/Hr	0	0	0	0
Run Time	5505	5505	5505	5505
Gas Cost	**27304**	**0**	**0**	**36691**

Reject Loss

	Water	UV	Solv	Solv w/Cntrl
Charge Rate/Hr	150	150	150	150
Run Time	5505	5505	5505	5505
Reject Rate	10%	2%	3%	3%
Reject Loss	**82571**	**16515**	**24773**	**24773**

Capital Cost

	Water	UV	Solv	Solv w/Cntrl
Total Capital Cost	115,000	220,000	0	338,000
Annualized Capital Cost	18,625	35,905	0	55,125

Income

	Water	UV	Solv	Solv w/Cntrl
Fixed Hourly rate	150	150	150	150
Hourly Feet Produced	21000	45000	24000	24000
Rate per Foot Produced	0.007142857	N/A	N/A	N/A
Annual Feet Produced	115,605,000	247,725,000	132,120,000	132,120,000
Annual Income	**825750**	**1769464**	**943714**	**943714**

Annualized Costs	**Fixed Production**			**Basin Scenario**
Retrofit System				
	Water	**UV**	**Solv**	**Solv w/Cntrl**
Ink	322524	390219	366348	366348
Gas	27304	0	0	32103
Electricity	20973	18958	11849	44362
Maint/Labor	149550	73105	98868	98868
Reject Loss	82571	7707	21675	21675
Capital	0	35905	0	55125
Total	**602922**	**525894**	**498740**	**618481**
Income ($150/Hr)	**825750**	**825750**	**825750**	**825750**
Net Income	**222828**	**299856**	**327010**	**207269**

Ink Cost

	Water	**UV**	**Solv**	**Solv w/Cntrl**
Ink Used	57800	33524	77452	77452
Ink Cost/Lb	5.58	11.64	4.73	4.73
Ink Cost	**322524**	**390219**	**366348**	**366348**

Maint/Labor Cost

	Water	**UV**	**Solv**	**Solv w/Cntrl**
Feet Processed	115,600,000	115,600,000	115,600,000	115,600,000
Speed	350	750	400	400
Run Time	5505	2569	4817	4817
Maint Time	1248	2985	676	676
Hours Charged	13506	8123	10985	10985
Labor Rate	9	9	9	9
Misc Cost	28000	6422	0	0
Maint/Labor Cost	**149550**	**73105**	**98868**	**98868**

Electrical Costs

	Water	**UV**	**Solv**	**Solv w/Cntrl**
Added kWH	11.25	41	0	56.25
kWH Cost	0.12	0.12	0.12	0.12
Added Cost Elect/Hr	1.35	4.92	0	6.75
Base Electrical/Hr	2.46	2.46	2.46	2.46
Run Time	5505	2569	4817	4817
Elect Cost	**20973**	**18958**	**11849**	**44362**

Gas Costs

	Water	UV	Solv	Solv w/Cntrl
Added Therms	8	0	0	10.75
Therm Cost	0.62	0.62	0.62	0.62
Added Cost Therm/Hr	4.96	0	0	6.665
Base Therm/Hr	0	0	0	0
Run Time	5505	2569	4817	4817
Gas Cost	**27304**	**0**	**0**	**32103**

Reject Loss

	Water	UV	Solv	Solv w/Cntrl
Charge Rate/Hr	150	150	150	150
Run Time	5505	2569	4817	4817
Reject Rate	10%	2%	3%	3%
Reject Loss	**82571**	**7707**	**21675**	**21675**

Capital Cost

	Water	UV	Solv	Solv w/Cntrl
Total Capital Cost	0	220,000	0	338,000
Annualized Capital Cost	0	35905	0	55125